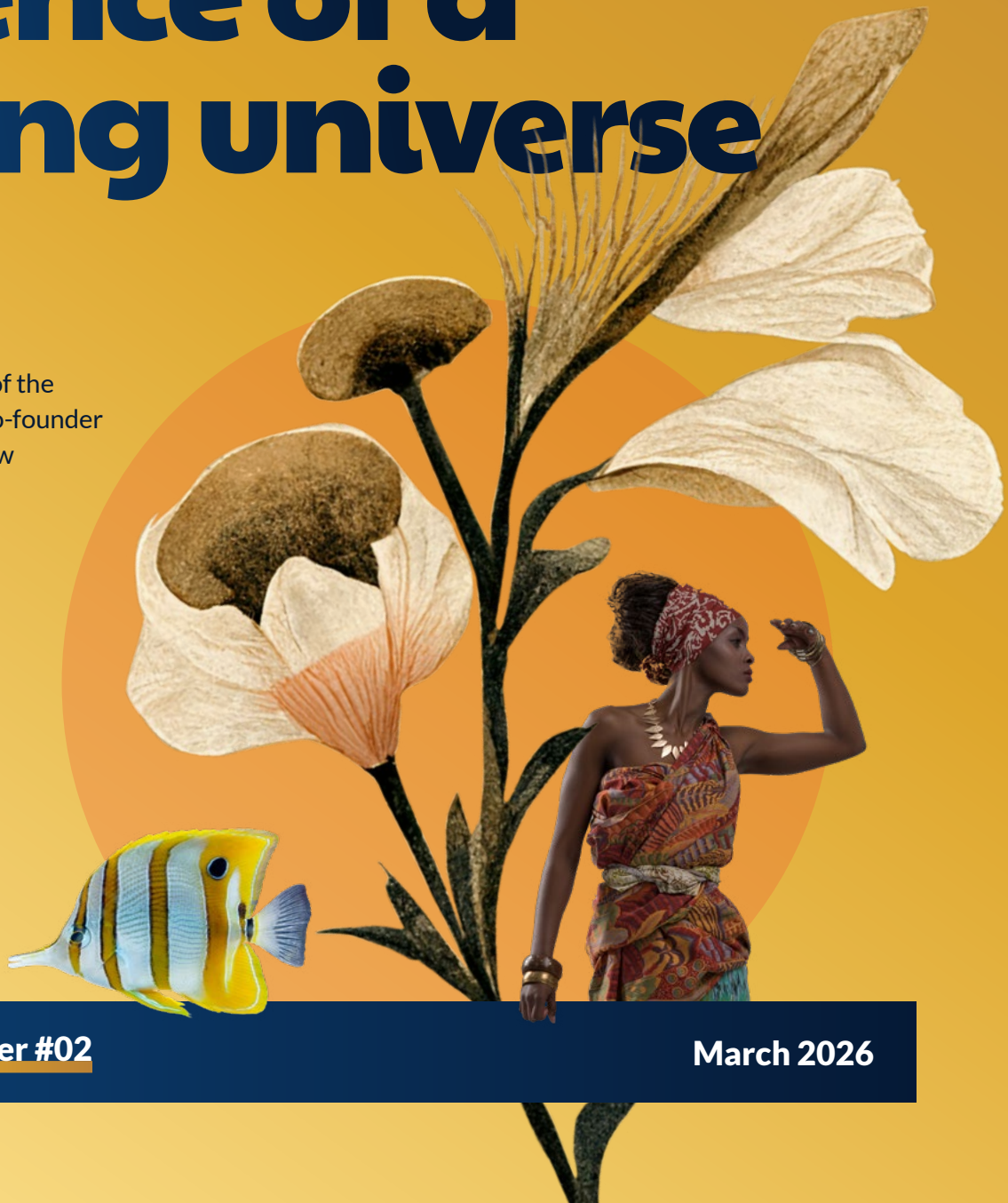
the fifth element



The unitive science of a living universe

Jude Currivan

Associate member of the Club of Rome and co-founder of WholeWorld-View



Discussion paper #02

March 2026

Contents

Foreword, by Raad Sharar, Programme Lead of Cultural Transformations at the Club of Rome 3

Background to discussion paper 5

A unitive cosmological framework 6

Key attributes of our universe 7

What these findings suggest 11

A new IN-SCIght of IN-formational SCIence: Expansion of three laws of thermodynamics to info-dynamics 11

The first law: conservation of energy, matter and in-formation 13

The second law: time, expansion and the growth of information 13

The third law: temperature, disequilibrium and ongoing emergence 14

Evolutionary emergence 15

Interstellar molecular clouds as 'birthing fields' for planetary systems 16

Planetary emergence 17

Biological emergence 19

Ecosystems 20

Convergence with universal wisdom teachings: Ancient and Indigenou s 21

Asking better questions: An invitation to discussion and collaboration 22

An invitation for discussion in this International Decade of Sciences for Sustainable Development 23

Foreword, by Raad Sharar, Programme Lead of Cultural Transformations at the Club of Rome

Every crisis tells a story about how the world is understood. The planetary challenges we face today reflect a way of knowing that has long treated life as fragmented and fundamentally separate. Science, despite its extraordinary explanatory power, has been deeply implicated in shaping this perspective. The modern scientific worldview emerged alongside assumptions that positioned mind outside matter, outside nature, and humans as observers rather than participants in the world they study. Anthropological studies of scientific domains have repeatedly shown that this separation was never fully achieved. Bruno Latour's observation that "we have never been modern" exposed the contradiction at the heart of this worldview: the simultaneous proliferation of entangled human-nonhuman hybrids and the persistent denial of their existence.[c] Donna Haraway's insistence on "situated knowledges" further dismantled the fiction of disembodied objectivity, foregrounding responsibility, partiality and relational accountability in scientific practice.[a] Tim Ingold, similarly, has argued against a world composed of inert objects, proposing instead a meshwork of ongoing processes in which beings come into form through relations of correspondence and movement.[b]

This paper explores the *unitive science of a living universe framework* (hereon, simply 'the unitive framework'). It enters this anthropological conversation by engaging developments within contemporary cosmology that challenge the ontological foundations of modern science itself. The unitive framework suggests that the energy and form of the universe arise from deeper, nonphysical sources, and that reality unfolds as meaningful information rather than lifeless matter. The paper investigates how in a holographic universe, the whole is not built from separate parts; instead, each part reflects the pattern of the whole. This view points to interconnectedness, mutual dependence and multiple dimensions as inherent qualities of existence.

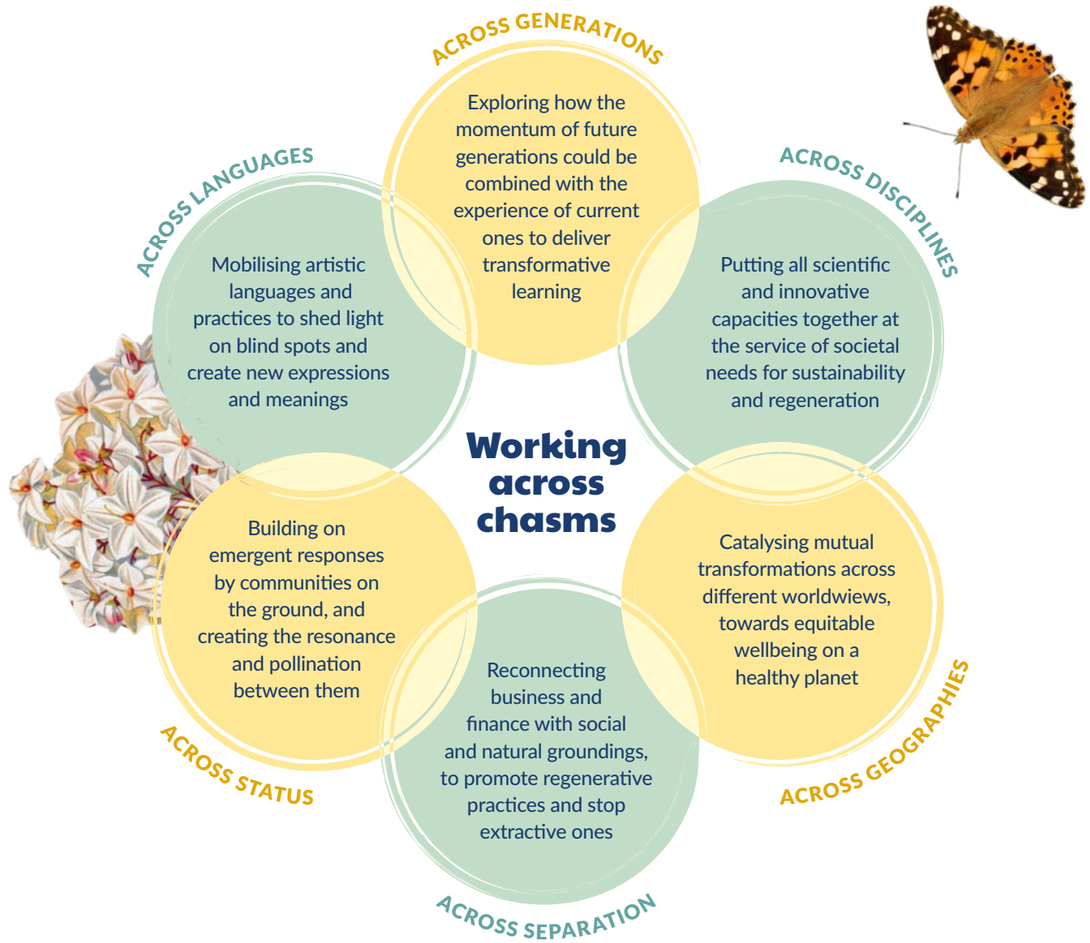
This framework represents more than a scientific hypothesis. It signals a shift in ontology: away from a dead, mechanical universe, towards a living cosmos characterised by emergence, participation and meaning. Rather than seeing consciousness as something produced by the physical world, the unitive perspective treats it as something the world already contains. This resonates strongly with Indigenous cosmologies and ancient wisdom traditions long marginalised by modern science, yet increasingly recognised across disciplines as coherent, empirically grounded ways of inhabiting the world.

The Fifth Element initiative seeks to ask better questions about the future of humanity by bridging the chasms between cultures, generations and knowledge traditions. In doing so, it aims to inspire new ways of engaging with the complex and systemic challenges that continue to constrain our collective ability to realise equitable wellbeing within a healthy and peaceful biosphere.

Bibliography:

a. Haraway, D. (1988). Situated knowledges: The science question in feminism and the privilege of partial perspective. *Feminist Studies, 14*(3), 575–599. https://doi.org/10.2307/3178066
b. Ingold, T. (2011). *Being alive: Essays on movement, knowledge and description*. Routledge.
c. Latour, B. (1993). *We have never been modern*. Harvard University Press.

The Fifth Element works across different chasms



This paper embodies a commitment to *pluriversality*: the capacity to hold multiple ontological traditions in dialogue without hierarchy. A unitive science, understood in this way, does not dissolve difference but provides a coherent space within which diverse ways of knowing may resonate. It responds to the "human gap" by resituating scientific inquiry within the web of life, grounded in ethics, relationship and responsibility.

That an anthropologist introduces a cosmologist's paper is itself a small enactment of the unitive approach this work advances. The importance of this paper lies precisely in its capacity to bridge domains that have been artificially separated, offering a cosmological framing that supports deeper learning, ethical responsibility and renewed possibilities for human and planetary wellbeing within an interconnected universe.



Background to discussion paper

In 2024, the launch of the International Decade of Sciences for Sustainable Development (IDSSD) initiative, with UNESCO as the lead agency, aims to "promote global collaboration through sciences to achieve a sustainable future." It recognises science as "a common good for humanity and reaffirms its fundamental role in humanity's quest for a development model that improves the human condition while preserving the planet on which our very survival depends."

Yet while technological progress has brought substantial benefits, the worldview on which modern science has stood since the late 19th century has also come at a high cost. This worldview has tended to frame reality as a material, mechanistic system composed of separate objects, largely stripped of inherent meaning or purpose. Such assumptions helped underpin the Industrial Revolution and the extractivist and exploitative economics models that emerged from it, many of which continue to drive the current catastrophic social and ecological trajectory.

The traditional scientific worldview has effectively dismembered our collective psyche, giving rise to what I refer to as a dis-ease of separation in how we relate to each other and the natural world. To truly confront the existential threats we face, we must do more than manage the symptoms of its pathology; we must heal our foundational rupture.

The Club of Rome has long argued that systemic transformation must begin with a transformation of worldview. This perspective is echoed in its recent paper on *Planetary Peace for Human Security*,[1] which posits that lasting solutions must address not only geopolitical tensions but also the deeper patterns of disconnection that drive them.

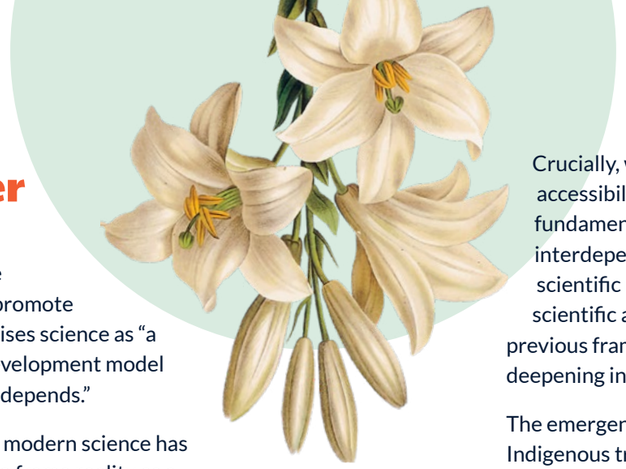
Its authors recognise the inadequacy of such disconnection and fragmented mindset to meet the challenges of our times, writing:

> *We understand that systems are based on assumptions and values. Systems transformation must be attentive to ideologies, and belief systems that undergird our social systems and social contracts. The challenge of ushering in planetary peace includes inner work on consciousness and becoming more deeply humans.*
>
> *To undertake the deep and rapid transformation required by the crises and which has been called for by the UN Secretary-General António Guterres, the embodiment of mutual interdependency with each other and our planetary home is vital."*

They note:

> *An evidence-based unitive perspective, one that recognises our mutual interdependence with one another and our planetary home, is essential to underpin and frame collective efforts. It enables an evolutionary perspective grounded in a cosmological and planetary context and affirms our emergent potential. In doing so, rather than perpetuating conflicts that continue to play out the illusion of separation, it can cultivate respect for pluriversality and support the embodiment of post-hegemonic values and ethical behaviours that are equitable, inclusive and rooted in experiential kinship and reverence for all life."*





Crucially, while going beyond materialism per se, such a unitive perspective is not beyond scientific accessibility. A unitive understanding refers here to a perception of reality that sees the universe as fundamentally relational and interconnected, in which humans, the Earth and the wider cosmos are mutually interdependent, and meaning arises through relationship rather than separation. Far from abandoning scientific rigour, its emergence is grounded in wide-ranging and empirical discoveries. Just as earlier scientific advances, such as quantum mechanics and relativity theory, expanded rather than discarded previous frameworks, so too does this perspective include and transcend the previous paradigm, while deepening inquiry into whether mind and consciousness may play a more fundamental role in reality.

The emergent vision and narrative of the unitive framework converge with ancient wisdom teachings and Indigenous traditions, reimbuing our universe with innate meaning and purpose and reunifying our minds, bodies and spirits, inseparable from their planetary and universal web of life.

This paper invites further exploration, dialogue, investigation and testing of such a unitive perspective based on evidence at all scales of existence and across numerous fields of research, together with proposed and interpretative theoretical framings. In offering a unitive cosmological and planetary underpinning and context, the discussion aims to further enable and empower efforts on human and planetary wellbeing.



A unitive cosmological framework

The Club of Rome Planetary Peace for Human Security paper also includes the following:

> *For many people — and indeed for everyone, if we dig deeply enough — the embodiment of interdependence is already inherent, it does not need to be newly learned. This unitive perception has long been the domain of universal wisdom, teachings and indigenous traditions. But what of the necessary evolution of the Western modern worldview? Interestingly, through the work of pioneers and scientific discoveries across all scales of existence and diverse fields of research, a universe of innate meaning and purpose is progressively and vitally being revealed: a universe that exists and evolves as an essentially living and wholly unitive entity. This convergence of mounting scientific evidence with the amazing intuitions of traditional knowledge, offers a pivotal and powerful opportunity to heal our collective affliction of separation to transform our world."*

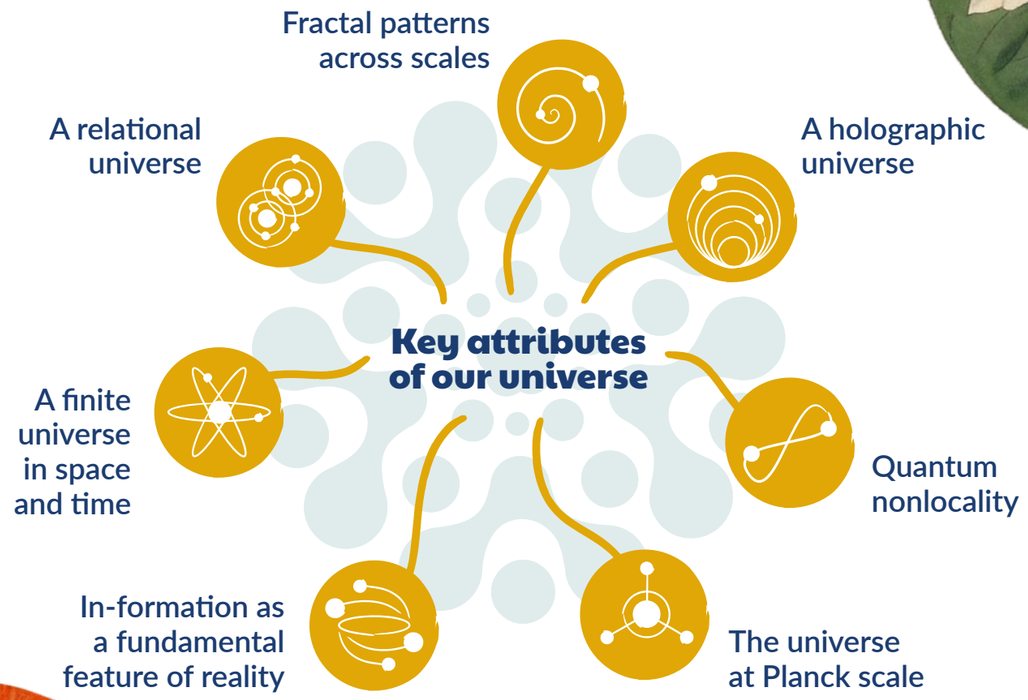
The scientific breakthroughs that gave rise to the two pillars of 20th-century cosmology, quantum theory (which describes matter and energy) and relativity (which describes space and time) have transformed our understanding of the universe, but they do not yet provide a complete picture of how it all fits together.

Not only have efforts to reconcile their apparently incompatible understanding of gravity been unsuccessful, but there is also a growing realisation that, by seeking to describe the physically manifest appearance of our universe, we must acknowledge and explore its deeper, unmanifest nature, from which that appearance emerges.

The key attributes, insights and evidence that enable the development of a unitive cosmological framework are summarised here as a basis for further discussion.



Key attributes of our universe



A relational universe

What science is revealing across physics and cosmology points towards a universe that is finite, relational and interconnected, encouraging us to rethink how energy, matter, space, time and meaning are related.

While the physical world is apparently solid, physicists are well aware that it is also extremely ephemeral. A hydrogen atom, for example is deemed to be 99.999999999999% no-thingness[2] with quantum field theory framing particles not as tiny discrete objects but as localised, vibrating, quantised and relational excitations of fields that permeate space-time.

Space and time are understood together as a single, self-contained framework for the universe; without this, the conservation of the universe's total energy and matter would not hold.

By 2013, multi-year analysis by the Wilkinson Microwave Anisotropy Probe (WMAP) also measured space, within a 0.4% margin of error, as being geometrically flat, which is also a requisite for the mathematical and universal equivalence of energy and matter.[3]

A finite universe in space and time

Increasing evidence is also pointing to our universe being finite in space and time. For example:

- Beginning as a finite event currently estimated at 13.8 billion years ago and given our understanding that relative space and time can only be considered as a combined and invariant space-time, it follows that finite time must correspond with finite space.
- In 2012, WMAP also reported an analysis of the Cosmic Microwave Background (CMB); relic radiation from an early epoch that fills the whole of space. In measuring the spectrum of CMB wavelength distribution and showing it has a finite cutoff, it also showed that on a logical basis there are no infinite physical quantities within space-time.
- In addition, the great majority of hydrogen in our universe, an estimated 95%, has already been processed into stellar nucleosynthesis,[4] suggesting a finite endpoint — or at least the completion of its evolutionary emergence.
- From its finite and minute beginning, as space expands and time flows unidirectionally from past to present and continues to progress into the future, the temperature of ambient space has fallen from an initial value of 10^{32} degrees K to a mere 2.7 degrees K above absolute zero, again pointing to a finite lifecycle.

In-formation as a fundamental feature of reality

An emerging body of scientific research suggests that information may not just describe the universe; it also plays a fundamental role in how physical reality itself is formed and organised.

Growing empirical evidence at all scales of existence and across numerous fields of research is revealing that digitised information, the basis of our communication technologies, also underpins and makes up all physical reality.[5, 6]

A finite universe can logically only embody finite information. There thus needs to be a mechanism for essentially unlimited nonphysical potential to become finitely manifest. Quantisation of energy-matter, with its innately discrete nature, is such a mechanism, enabling finite information to be expressed within space-time.

We are familiar with the idea of the 1s and 0s of bits being the digital building blocks for computerised data processing. But it is being discovered that such bits are the simplest expression, the literal building blocks, of all finite information, enabling its processing with the minimum energy and maximum stability. Combining bits, rather like building a house out of bricks, enables any and every possible outcome — and multiple outcomes — to be expressed as efficiently as possible.

Essentially, the energy and matter of our universe are quantised because information is digitised and thus quantised, and universal information is quantised because it is the most effective means for its communication.

Crucially, accumulations of the 1s and 0s of this universal 'alphabet' combine meaningfully, as instructed by the algorithmic laws of physics, to literally 'in-form' as energy-matter. This is expressed in interdependent and dynamic relationships throughout space-time.

In 2011, information was experimentally shown to be as 'real' as energy-matter, as the deletion of a single bit of digitised information released heat, in line with theoretical predictions by Leo Szilard and Rolf Landauer.[7]

How intrinsically meaningful in-formation may be expressed in complementary ways as the energy-matter and space-time appearances of our universe will be posited and elaborated in A New IN-SCIght of IN-formational SCIence section later in this discussion paper.

As famously proposed by physicist John Archibald Wheeler, 'It from bit' may now be expanded further to 'It IS bit'.

The universe at Planck scale

To understand how the universe may be structured at its most fundamental level, it is helpful to look at the smallest scales at which physical reality can meaningfully be described.

Named after quantum physicist Max Planck, the manifest appearance of our universe emerges at the Planck scale of existence and is embodied in five universal phenomena: energy, matter, space, time and temperature.

These relate to each other regardless of the units they are measured in: whether in our human scales of measurement or those of a self-aware and scientifically adept species anywhere or any-when in our universe.

For example, as energy-matter and space-time are woven together by the speed of light, the minute Planck time of approximately 10^{-44} seconds is the duration for light to travel the Planck length of around 10^{-35} metres.

So, consequentially, the speed of light in a vacuum normalises to a rate of one Planck length per one Planck time.

The Planck epoch is named as the current understanding of our unfolding and finite universe from its first moment of one Planck time, with a miniscule diameter of one Planck length.

As space expands and time flows, the temperature of our contained universe has since fallen. From the start of its lifecycle, with its Planck temperature of one, in our measure a torrid 10^{32} degrees Kelvin, to its current ambient temperature of 2.7 degrees Kelvin to a projected endpoint of close to absolute zero.

Quantum nonlocality

Another key discovery challenging a purely local and mechanistic view of the universe is the phenomenon of quantum nonlocality, which shows that deep connections exist across space and time.

Within space-time, no signal can travel faster than the speed of light, thus maintaining causality throughout the universe. However, quantum mechanics only works if also and at a foundational level our entire universe is a coherent and essentially unitive entity; a phenomenon known as universal nonlocality and acknowledged by the award of the 2022 Nobel Prize for Physics to Alain Aspect, John Clauser and Anton Zeilinger.

The work of the Nobel laureates and others has probed this in the laboratory and progressively at planetary scales, and in 2018, a multi-affiliated team led by MIT researchers, building on their own experiment the previous year, did so at a cosmological level. In entangling photons of light in their laboratory with stellar photons from 600 light years away and testing the entangled measurements triggered by light from two quasars (extremely active galactic centres), the most distant being 12.2 billion light-years away, they succeeded in verifying the universal nature of nonlocality according to the theoretical framework developed by John Stewart Bell.[8]

With a Nobel Prize for Physics widely viewed as only given for 'settled' science, the award essentially accepts the reality of our universe fundamentally existing and evolving as a nonlocally unified entity; its existential unity pertaining to the entirety of its space-time as well as the totality of its quantised energy-matter.

A holographic universe

Building on these insights, some cosmologists have proposed that the structure of the universe itself may be best understood as emerging from deeper informational relationships.

Extending from studies of black holes to our entire universe, a growing number of cosmologists have also developed the so-called holographic principle, to model its four-dimensional appearance (three dimensions of space and one of time) as a holographic projection of a two-dimensional boundary (one dimension of space and one of time).

Backed up by complementary research on gravity and universal forces in general, the holographic universe has now become perhaps the leading and most-investigated framework of cosmology.[9] Its significance is reflected in the setup of the Celestial Holography initiative at the Perimeter Institute in Canada as a collaborative hub for further research and experimental measurement.

Underpinned by and arising from non-manifest realms of universal causation, the appearance of its characteristic in-formational patterns and relationships, known as fractals, is self-similar and self-affine. Embodying innate existential meaning and evolutionary emergence, fractals have been found to scale up and down across huge differences in scale and across numerous and wide-ranging phenomena, as described in the next section.

It is at the minute Planck scale triangular area, each side comprising a Planck length and embedding a digitised bit of in-formation, that the holographic boundary of our universe is considered to be pixelated and projects the digitised in-formation of its appearance and emergent reality.

As space expands from its minute beginning and time flows unidirectionally forward, the holographic model shows how its manifestation is thus able to embed ever more and innately meaningful in-formation through its evolutionary lifecycle.

Fractal patterns across scales

Fractals, as recurring patterns that repeat across vastly different scales, make visible the deeper interconnected structure of the universe.

The largest scale of such fractal patterns has been measured in temperature fluctuations throughout the cosmic microwave background, or CMB, the relic radiation left over from a very early epoch of our universe and which fills the whole of space.[10]

At smaller scales, fractals have been discovered in myriad phenomena. From where electrons of ensembles of atoms cluster fractally when an atom undergoes a phase transition between behaving as a metal and an insulator,[11] chemical processes including corrosion[12] to planetary phenomena including the shapes of coastlines[13] and clouds.[14] Fractals are also embedded in climate patterns,[15] geology and geophysics.[16]

Extending to our entire solar system, they show up in the solar wind, the stream of charged particles continually emitted by the outer atmosphere of our Sun.[17] Further afield and at vastly larger scales still, fractal patterns have been discovered in the clustering of great numbers of galaxies.[18]

Crucially, and further emphasising their meaningfully in-formed nature, our collective human behaviours also reflect fractals, including: movements of stock market prices analysed by the 'father of fractals' Benoit Mandelbrot[19]; internet traffic, website links and data routes[20, 21, 22] email, postal mail, social internet group communications and web browsing,[23, 24, 25] and geographic and time-based usage of mobile phones.[26]

Linking such 'natural' and 'human' phenomena even further, in 2015, astrophysicists tracked how, by looking at their respective population densities of people and stars, cities grow in the same in-formationally patterned ways that galaxies form.[27]

Researchers have even uncovered self-similar relationships, known as power laws, linking the relative frequencies and logarithmically destructive powers of earthquakes with the occurrences and scales of deaths from human conflicts.[28, 29, 30]

In neuroscience, the introduction of fractals for quantitative analysis has ushered a major paradigm shift and enabled a universal language and wholistic approach to brain complexity.[31, 32]

In 2017, recognising the increasingly wide-ranging evidence, the Galileo Commission was founded with a view to investigate science beyond its materialistic assumptions. In 2018, with 90 advisors representing 30 universities worldwide, the commission published a Report entitled *Beyond a Materialist Worldview – Towards an Expanded Science*.[33]



What these findings suggest

Taken together, this emerging and evidence-based cosmological framework invites further discussion and exploration. It suggests that the familiar appearance of energy, matter, space and time may arise from deeper underlying processes, and that these processes may be best understood in in-formational and relational terms, including through holographic models.

In a holographic framework, each part of the universe carries information about the whole. From this perspective, reality can be understood as inherently interconnected and relational, unfolding across multiple dimensions rather than as a collection of isolated objects.

This view also opens a growing line of inquiry into the nature of mind and consciousness, suggesting they may not be things we possess, but instead that they are aspects of, and even foundational to, who we are and how the universe expresses and knows itself. Seen in this way, a unitive perspective is not presented as an ideal to be reached, but as a way of perceiving our existential reality that invites deeper reflection and testing.

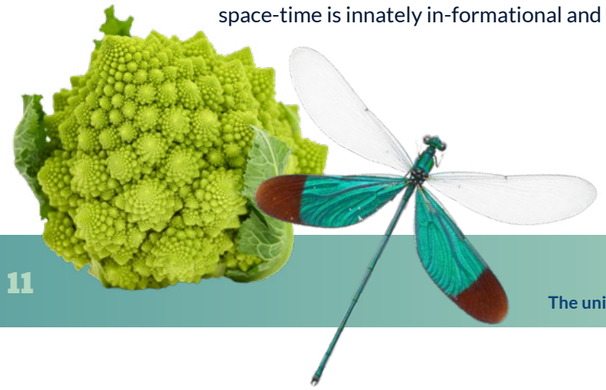
Rather than a universe empty of meaning and purpose, the evidence discussed here points toward a universe rich in emergence and possibility, with human beings participating as part of its ongoing unfolding.

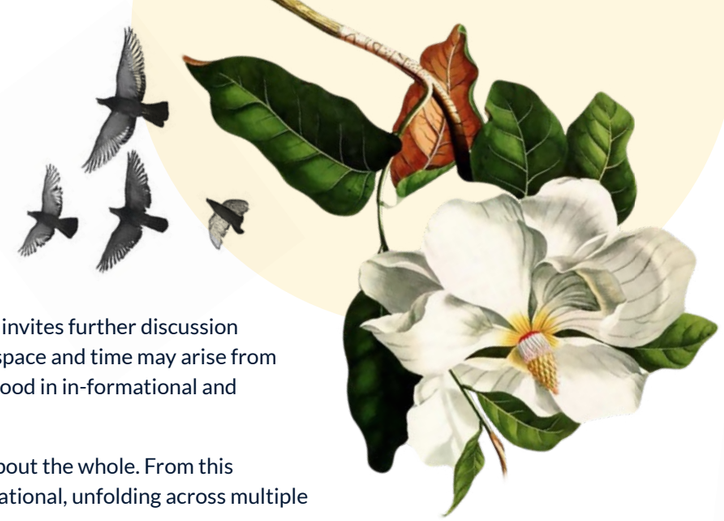
A new IN-SCIght of IN-formational SCIence: Expansion of three laws of thermodynamics to info-dynamics

The growing body of evidence supporting a unitive in-formation-based perspective and cosmological framework opens the possibility of reinterpreting some of our most fundamental physical laws. In this view, the three laws of thermodynamics could be reframed into laws of in-formation or info-dynamics. This reframing is offered as a way to explore whether in-formation-based principles might help bridge longstanding gaps between quantum mechanics (which, as mentioned above, describes energy-matter) and relativity (which describes space-time).

This section proposes my own development of this expanded perspective and explicitly invites further discussion and investigation.

The following restatement of all three laws is based on the joint propositions that our entire universe is a contained, finite and unitive entity, and that its appearance of energy-matter and space-time is innately in-formational and holographically manifested.









Laws of in-formational dynamics

Laws of thermodynamics

1st The total energy of a contained system is conserved through time

In-formation expressed as the quantised energy-matter of our universe is conserved through the lifecycle of our universe

2nd The total entropy of a contained system always increases over time

In-formation expressed in-tropically as the space-time of our universe, always increases through time and as space expands

3rd The entropy of a contained system approaches a constant value as its temperature falls to absolute zero

As the temperature of our universe drops, in-formation in-tropically increases in inverse proportion





The first law: conservation of energy, matter and in-formation

Seen through an informational lens, this section explores whether the familiar conservation of energy and matter might also be understood as the conservation of meaningful in-formation expressed as energy-matter, across the lifetime of the universe.

The first law of thermodynamics states that the total energy of a contained system is conserved through time:

- As energy and matter are equivalent: $E = mc^2$, it follows that the total energy-matter of our universe is conserved;
- As quantum theory is a description of universal energy-matter, this is its simplest and most generalised statement;
- In-formation is expressed as quantised energy-matter.

The first law of info-dynamics can thus state that:

> *In-formation expressed as the quantised energy-matter of our universe is conserved through the lifecycle of our universe.*

The second law: time, expansion and the growth of information

One of the most, if not the most, foundational concepts of thermodynamics is that of entropy. Expanding the traditional concept of entropy as the number of energetic microstates of a system, to the information content of a system,[34] both of which are described by the same Boltzmann equation, resolves the misperception of the entropy of a contained system (such as our entire universe) going from order to disorder over time, to its embodying increasing informational content. I have termed this concept intropy.

Consideration of the inherently meaningful in-formational nature of our universe, expanding entropy further to intropy then posits how everything within it contributes to its overall in-tropic evolutionary flow, from simplicity to complexity and individuated self-awareness.

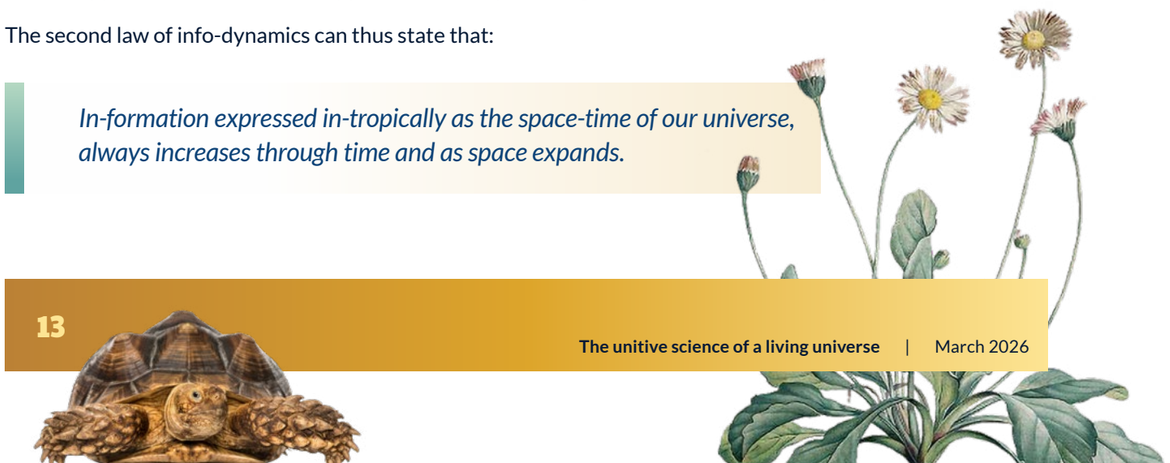
Here, the discussion invites a shift in how entropy is understood, suggesting that the universal flow of time and expansion of space may also be seen as the evolutionary accumulation of information and complexity.

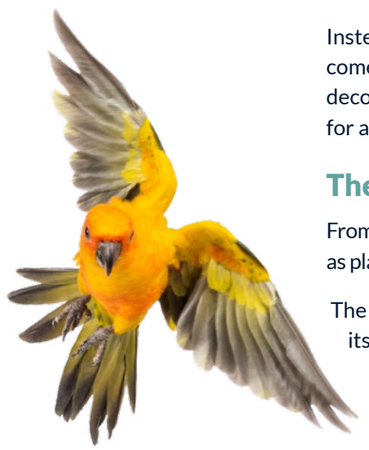
The second law of thermodynamics states that the total entropy of a contained system always increases over time:

- Relative time and relative space are combined as invariant space-time;
- Space-time began in a state of lowest entropy[35] and thus the total entropy of our universe always increases over space-time;
- As relativity theory is a description of space-time, this is its most simple and generalised statement;
- Entropy can be restated as intropy and universally meaningful in-formation as in-tropy.

The second law of info-dynamics can thus state that:

> *In-formation expressed in-tropically as the space-time of our universe, always increases through time and as space expands.*





Indeed, the flow of time itself, pixelated at the Planck scale may thus be considered as the in-tropic accumulation of the in-formational content of our universe through its lifecycle.

This unitive perspective also removes any need for the notion of negentropy or syntropy, as a sort of reversal of universal entropic flow (misperceived as being from order to disorder) in open sub-systems, such as a planet or a biological organism, which exist far from states of equilibrium.

Instead, their characteristic and ongoing flowthroughs and dissipations of unutilised energy, enables them to come into individuated space-time coherence and then continue to accumulate in-tropy before eventually decohering. For example, as a consequence of the removal of their energy source (in the case of a central star for a planetary system) and/or the completion of their biological lifecycle for an organism.

The third law: temperature, disequilibrium and ongoing emergence

From this perspective, falling temperature at a universal scale and sustained energy flows in open sub-systems such as planets and ecosystems are explored as conditions that allow emergence and evolutionary potential to continue.

The third law of thermodynamics states that the entropy of a contained system approaches a constant value as its temperature falls to absolute zero.

In such a contained system (as is our entire universe) and in info-dynamic terms, temperature is in an inverse relationship with in-tropy, and their interplay represents the unfolding cycle of the system; with in-tropy increasing and temperature correspondingly decreasing through space-time.

Our universe began at its highest Planck scale temperature and lowest Planck scale in-tropy, and ever since, as space has expanded and time flowed, in-tropy has increased and temperature has fallen in an ongoing cycle. This cycle will continue until the ambient temperature of space falls to quantum-scale fluctuations adjacent to absolute zero.

In the open and dissipative sub-systems of our universe, including planets, ecosystems and people, temperature is also a measure of their disequilibrium with their surroundings.

Continuing energy flows through and dissipation of excess energy/in-formation from such open sub-systems in disequilibrium are required to maintain their temperatures and so sustain their ongoing potential to actualise further in-tropy through time.

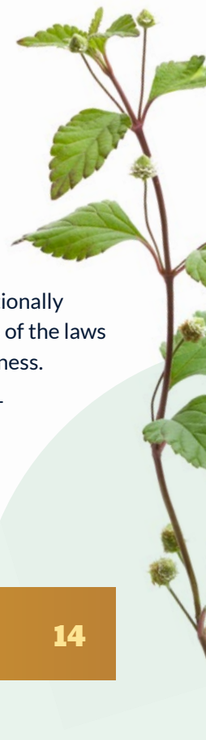
The third law of info-dynamics can thus state:



> *As the temperature of our universe drops, in-formation in-tropically increases in inverse proportion.*

In summary:

- The first law of info-dynamics enables our universe to meaningfully exist, expressed as in-formationally quantised energy-matter. While conserved overall through space-time, the relational algorithms of the laws of physics enable changes in form and from simplicity to complexity and individuated self-awareness.
- The second law of info-dynamics enables our universe to purposefully evolve by increasing its in-formational content (in-tropy) as space expands and over time.
- The third law of info-dynamics shows how the expansion of space and reduction of temperature correlates with increasing universal in-tropy over time, effectively driving the emergent processes of its universal lifecycle.



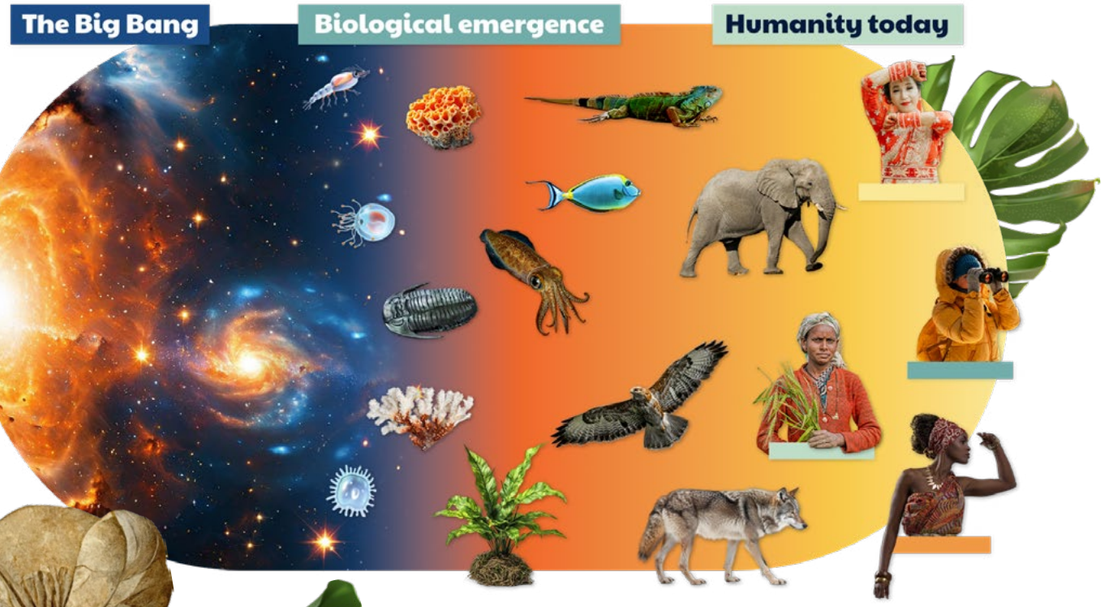


Rather than a universe empty of meaning or purpose, the evidence discussed here points toward a universe rich in emergence and possibility, with human beings participating as part of its ongoing unfolding.

If the universe is understood as relational, in-formational and dynamically interconnected, a further question arises: how do novelty, complexity and life come into being within such a universe? Addressing this question shifts the focus from the underlying structure of reality to the processes through which new forms, relationships and capacities emerge over time.

Evolutionary emergence

Evolutionary emergence describes how increasingly complex structures and behaviours arise from simpler interactions over time. The lens of evolutionary emergence offers a foundational way of exploring how a meaningfully in-formational and unitive universe may give rise to increasing differentiation, creativity and self-organisation.



This emergent unitive cosmology describes a universe that began some 13.8 billion years ago, not in the implied chaos of a big bang but as the first moment of a tiny, incredibly ordered, extremely fined-tuned and ongoing 'big breath'.

Since then, as space has expanded and time has flowed, the universe has evolved from its initial simplicity to ever greater complexity and diversity; from hydrogen and helium atoms to stars, black holes, galaxies, planets and people. Fundamental to its four-dimensional structural appearance and vitally for the evolution of complex biological organisms, is gravitation.

Treating gravity as an emergent consequence of the in-formational and holographic structure of space-time appears to offer a more literal interpretation of general relativity than considering it as a fundamental force and might account for why physicists have been as yet unable to detect gravitons, gravity's hypothesised and quantised force-carrier particle. While very much a work-in-progress, the insight that gravity may be a consequence of the in-formationally in-tropic nature of space-time, and that there are clear links between gravity and intropy,[36,37,38] points to gravity being an emergent in-tropic phenomenon and vital for space-time orientation. This understanding of gravity is key to the findings of the loss of phenotype identity in micro and zero gravity[39] and the role between gravity and cellular identity[40] for biological organisms.

Throughout the entire history of our universe, gravity and its in-tropic role in helping to guide space-time in-formational forms has been crucial from stellar nucleosynthesis to interstellar molecular hydrogen clouds to planetary systems and the emergence of biological complexity.

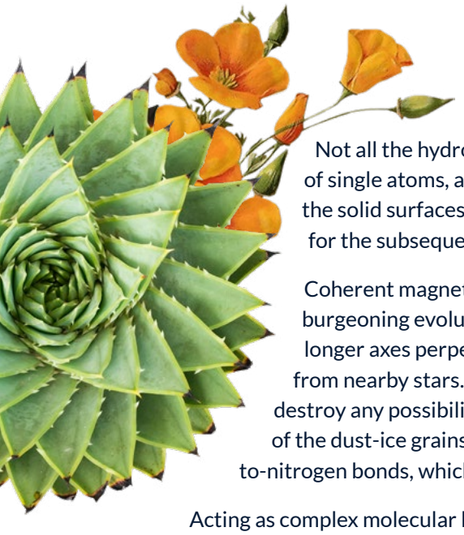
Interstellar molecular clouds as 'birthing fields' for planetary systems

Within our own and likely billions of other galaxies, lying between the stars of galactic discs and embedded within their spiral arms, are vast interstellar clouds of gas and dust garnered as a rich elemental legacy from the explosive demise of earlier generations of stars. Some are much denser than the ambient interstellar medium and it is within these, rich with molecular hydrogen, where new stars and planetary systems gestate and are birthed.

Such clouds' collective components also include multi-elemental dust grains with cores of silicon or carbon-rich materials and gases including polycyclic aromatic hydrocarbons or PAHs,[41] formaldehyde, non-crystallised ice grains and low-level ultraviolet (UV) light. In the low gravity and low temperature conditions, their intricate mix enables the synthesis of a varied range of other and more complex organic molecules.

The processes are inherently collaborative and in-formationally complex. The cold conditions of the cloud, around 10 degrees K or so above absolute zero, hinder colliding hydrogen atoms from directly forming hydrogen molecules. However, the surfaces of dust grains acting as hosts for the highly vibrational bonding, quickly dissipate the excess energy incurred and so stabilise the reaction. This then enables the production of profuse amounts of molecular hydrogen as a vital prerequisite for more complex interactions to occur.





Not all the hydrogen in the clouds, though, is molecular. Much of it exists in the form of single atoms, and these too are vital for combining with oxygen atoms, also hosted by the solid surfaces of the dust grains, to form non-crystalline ice; which is, again, required for the subsequent emergence and evolution of organic life.

Coherent magnetic fields flowing through the clouds provide yet another service to the burgeoning evolutionary potential by aligning the dust grains, which then spin with their longer axes perpendicular to the field and so diffuse and polarise the incoming UV light from nearby stars. This scattering reduces the intensity of the light that would otherwise destroy any possibility of complex molecules forming. Instead, the low level of its irradiation of the dust-ice grains energetically triggers the formation of carbon-to-carbon and carbon-to-nitrogen bonds, which are foundational for the creation of organic molecules.

Acting as complex molecular laboratories, their elemental abundance and finely-tuned physical and chemical properties enable all the prebiotic building blocks of future biological life to come into being.[42,43,44,45]

Significantly, all five nucleobases of DNA and RNA were discovered in samples collected from the 4.6 billion-year-old asteroid Bennu, returned to Earth for analysis and reported in January 2025, showing their genesis in such precursor clouds.[46]

By absorbing energy from gas-dust interactions and UV light, the clouds also dissipate excess energy as heat, keeping their interiors cool and at the perfect temperature to nurture the potential for such future emergence.

The diffused UV light, however, remains sufficiently strong to partially ionise the hydrogen gas, thus freeing its electrons from their proton nuclei. The coherent polarisation of the light also imposes a specific direction of spin, clockwise or counterclockwise, on the electrically charged electrons of the ionised material. Imbuing such chirality on each type of molecule subsequently enables the future optimisation of in-formational flows in numerous biological processes.

The final factor enabling the emergent birth of planetary systems is the combined frequency and explosive power of supernovae. Interstellar clouds form at the intersections of their shock waves, and subsequent waves trigger the gravitational collapse 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.

Planetary emergence

Some 4.6 billion years ago, in the depths of such a gestating cloud, shock waves from a nearby supernova did indeed likely trigger a gravitational collapse, leading to the formation of our planetary home — I refer to as Gaia — and our entire solar system.[47] As the collapse continued, the infalling material 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.



The relational dynamics of such protoplanetary disks and the magnetic fields that pervade them are themselves key for enabling planetary systems, including our own, to evolve. Magnetic fields interacting with electrically charged ionised 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 discs. This slows the axial spin of the former and steadies their development while differentiating orbital spin rates within the material that comprise developing planets, into harmonic periodicity that supports future orbital stabilities. It thus sets the stage for the next great leap in universal evolution.

For planetary systems, however, to then nurture biological emergence, a series of interdependent conditions seem vital. While a work-in-progress, the following appear to be important factors in considering whether a planet (or planetary moon) may harbour the potential for further biological complexity:

- A planetary/lunar body needs to be relatively stable on a long-term basis in both its structure and orbital dynamics, and crucially as an energetically open and dissipative system. It needs to be able to utilise external and internal energy sources to provide the structural and metabolic features 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 radioactive decay within its geosphere as long as neither of these are too disruptive. Temperature differentials maintained between them and outer space are in-tropic measures of their ongoing ability to sustain biological life and their evolutionary potential.
- 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 as such, 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.
- The inherent gravitational gradients of a planet or planetary moon 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.[48,49,50]



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 required to nurture the level of sophistication that has evolved on our planetary home over 4 billion years.

Some of the factors that especially pertain to Gaia's ambient gravitational field and consequential in-formational and in-tropic aspects — which have then enabled complex biological emergence — are:

- 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, engendering varied environmental niches and change and thereby driving biological emergence and diversity[51];
- As a 'rocky' planet, embodying a medium scale gravitational field and surface solidity and environmental niches for an abundant variety of biological expressions;
  - 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 of geosphere, hydrosphere, atmosphere and biosphere, comprises all 94 natural elements and crucially a surface availability of the 60 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, which themselves help to drive evolutionary processes.

Biological emergence

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

The innate in-formational intelligence and adaptability of the DNA/RNA genetic code is such that from the emergence of its nucleobases in molecular interstellar clouds and bequeathed to the earliest stages of our solar system, it has remained constant for over the 4.5 billion years lifetime of Gaia. It embeds the same structure for all of the profusion and evolutionary complexity of our planet's organic children and perhaps numerous other organic life-forms elsewhere.

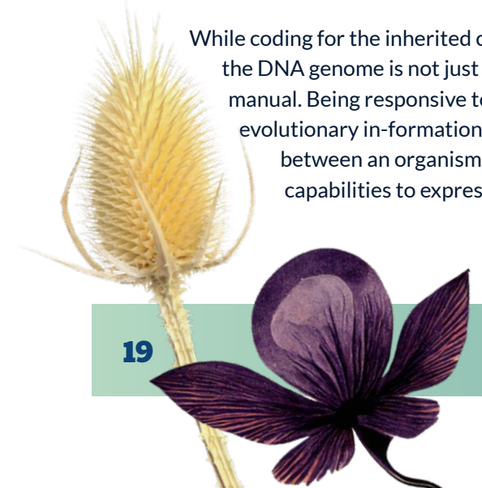
The foundational building blocks of the structures of DNA and RNA are themselves in-formationally intricate and optimally fit for their complementary purposes as evidenced by the following examples:

- The double-helix and chemical composition of DNA has been estimated to be a one in a million and right-first-time structure[52];
- The complementarity of DNA and RNA and their likely co-evolution; with DNA optimised as a genetic read/write in-formational template and multiple versions of RNA taking on a number of transference, communications and adaptive roles[53];
- The number of amino acids required for protein construction and their fractal folding for structural complexity are optimal in terms of supporting diverse and flexible morphologies[54,55];
- The co-evolutionary emergence of enzymes is able to radically speed up biological processes that are crucial for numerous threshold reactions. An extreme example is the enzyme Orotidine 5'-monophosphate decarboxylase (ODCase), which accelerates the formation of uridine 5'-phosphate, an essential precursor of RNA, by a factor of 10^{17} — reducing the reaction time from the lifetime of our universe to less than a second.[56]



While coding for the inherited characteristics and functions of an organism, the DNA genome is not just a read-only and thereby unchangeable instruction manual. Being responsive to ongoing, active, adaptive and potentially evolutionary in-formational processes within an entire organism and between an organism and its surroundings, it also has read-write capabilities to express its genes in different ways.





As such, the genetic code is not the controller of the organism but, rather, its servant. Indeed, if their genomes are removed, while then unable to replicate, repair damage or undertake genome-linked adaptations, cells can still continue to metabolise and sustain all their co-ordinations and communications activities both within themselves and between each other.

The reappraisal of the role of DNA and the genome has gone along with a revolutionary overhaul of the standard neo-Darwinism model of biological evolution. The standard model assumes that — based on the hereditary template of its genome, through random mutations with evolutionary benefits that enhance the organism's fitness to its environment (adaptation), natural selection, and over long periods of time — evolutionary progress is gradually accomplished.

However, discoveries are showing that, in addition to much more dynamic roles in gene expression beyond the genome and the related processes of replication and proactive adaptation through mechanisms including epigenetics and horizontal gene transfer (HGT), neo-Darwinism's foundational presumption of beneficial random mutations being the primary driver of evolution is fundamentally flawed.

Instead:

- RNA checks and balances in-formationally guide purposeful and beneficial evolution through various mechanisms including HGT and sometimes for radical and rapid emergence. These are all meaningfully and purposefully engaged[57,58]
- Extensive coding corrections reducing the frequency of random mutations to a minimum. For example, from an estimated error rate in human protein synthesis of one in 10,000 copies in transcribing initial DNA instructions via further controls as the coding is messaged, transferred and then used by various types of RNA to construct the requisite protein, coding corrections improve the error rate to a miniscule one in more than a billion copies.[59]

Ecosystems

Furthermore, as Darwin himself came to recognise, there cannot be an understanding of such evolutionary processes while attempting to separate a biological entity from its environment.

Socioeconomic distortions inflicted on neo-Darwinism's ecologically driven "survival of the fittest" have drawn a picture of constant conflict between organisms as being the main selector of their evolutionary fitness. While competition for environmental niches and resources do have their roles, it is rather cooperation and holarchic collaboration that are being found to drive evolutionary complexity.

Often and where feasible, evolutionary montages of preassembled organic components assemble and include attributes from different lineages, rather than undertaking longer and more energetically costly sequential evolutionary routes.

Such reticulate processes facilitate entire ecosystems to dynamically co-evolve, enabling optimal balances between their resilience and adaptability.[60] Precisely poised between coherence and disorder and known as critical states, interactions within their networks are as large as the ecosystems themselves.

These systems are nonlinear; a small change can cascade into a much larger effect. The introduction or removal of just one species to or from a healthy ecosystem affects all others, and an apparently minor destabilising cause



can result in major impacts, sometimes across the entire system. Such alterations are capable of leading to either extinction or emergence. These occurrences can take place when the species within an ecosystem are co-dependent and so specialised that they are also unable to adjust to environmental changes. There is no need then for the catastrophic wipe-out of a large portion of their populations as the removal of a single species in such a critically balanced network can be enough to generate ecosystem destruction.

Ecosystems in critical states have a number of characteristics that help them attain their dynamic optimisation between resilience and adaptability. They do this in part by maximising the speed at which in-formation passes through them.[61]

Analysis of their composite relationships in terms of the evolutionary fitness between their nonbiological environs and their biosphere shows that their complexity embody fractal structures and are highly scale-invariant. Rain forests are a good example. Species and populations can display the pink noise of 1/f frequency distribution behaviours, revealing that they resonantly couple and amplify in-formation channels and processes and are able to do so for considerable periods of time.

Where diversification emerges and where extinctions happen across these critical ecosystems, they also appear to exhibit power-law relationships between their size and rates of occurrences. This points to there being no such thing as an average example. Instead, they all embody emergence-extinction events across a continuing spectrum of scale and frequency.[62]

The evidence strongly indicates that all such ecosystems are fractally nested and in-formationally coherent and that their biodiversity is essential for their wellbeing. Increasingly, discoveries are revealing that the innate interrelatedness of their biosphere with the geosphere, hydrosphere and atmosphere of their environments not only applies in their locale but extends as a planetary-wide *gaiasphere* and can only be fully understood in this context.

Convergence with universal wisdom teachings: Ancient and Indigenous

This emergent evidence-based unitive understanding of the nature of our universe is revealing a cosmology of existentially meaningful and evolutionary purposeful universal consciousness. By recognising unity with the ultimate 'great mystery' or 'source' of all being and inherent integration with universal sentience, it also contextualises biological emergence as expressions of an evolving universe that in its entirety is essentially 'living'.

On planetary and human levels, the universal and archetypal relationships now being evidentially revealed are also reflected in spirituality-based, universal and Indigenous wisdom teachings and traditions.

Instead of the apparent separation of our inner and outer awareness, and devaluation of our inner perception, this unitive perspective and its narrative value our inner cognition and invite heart-centred wisdom. In doing so, they also honour and respect the complementarity of feminine and masculine yin-yang attributes, relatedness and balanced perspectives and their co-creative synergies. Thus, a perception of universal unity expressed in diversity offers to guide us to a wholeness of the inner being and outer doing in our lives and support us in integrating our innate health and wholeness, both individually and communally.

Wholistic approaches to healing and emergence founded on right relationships, based on resonance, coherence and trust — underpinned by the innate in-formational meaning and in-tropic nature of reality as considered in this paper — welcome further reflection and dialogue.



Asking better questions: An invitation to discussion and collaboration

This discussion paper posits that reframing our worldview to an evidence-based unitive perspective offers a societal and cultural opportunity to consciously usher in our next and evolutionary steps as a species. In doing so, it raises several important questions.

On the species level:

How might a more relational and interconnected understanding of the universe influence how we see ourselves and our responsibilities to one another?

At a personal and cultural level:

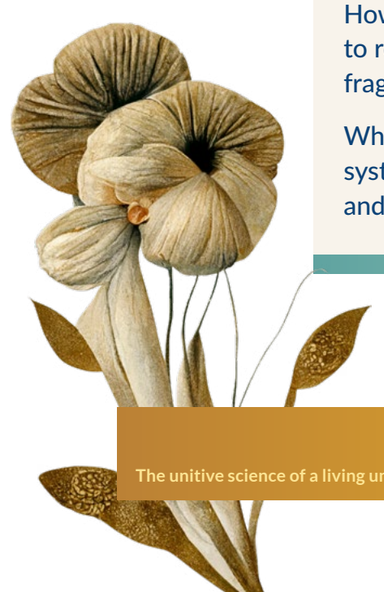
In what ways could such a perspective help re-contextualise today's overlapping meta-crises not only as breakdowns, but also as moments of potential breakthroughs, or even metamorphosis?

At an organisational and societal level:

How might a unitive perspective inform approaches to reconciliation, peace-building and healing social fragmentation?

What could it mean to design education and learning systems that reflect interdependence, planetary limits and emergent potential long-term responsibility?







At a global and systemic level:

How might this perspective contribute to new ways of thinking about governance in a pluralistic and interdependent world?

What questions does it raise about how we shape economic systems, technological innovation and artificial intelligence in ways that serve long-term planetary wellbeing?

How might understanding humanity as part of a living Earth system influence what it means to be a good ancestor?[63]

An invitation for discussion in this International Decade of Sciences for Sustainable Development

The limited and fragmented nature of human sensing and perceptions bolster an illusionary perception of reality, which when allied with a secularly constrained approach to investigation has resulted in a mechanistic worldview. Despite progressive and increasingly compelling evidence to the contrary, this is the worldview that has prevailed since the late 19th century. However, some scientists are now striving to reshape our fragmentary thoughts, senses, perceptions and approaches, combining Enlightenment with the "Enlivenment" that Andreas Weber and other biologists, Thomas Berry and other ecologists and Brian Swimme, myself and other cosmologists, as well as many others, are harkening to.

Such a unitive framework enables a unitive mindset founded in a cosmological and planetary context, universal values and ethical behaviours that recognise and embody our emergent potential. In doing so, rather than being part of the many conflicts that continue to play out the illusion of separation, it can guide the peaceful embodiment of universal values and ethical behaviours that are equitable, inclusive and based on experiential kinship and reverence for all life.

Offering a radical re-envisioning of not only how the world is as it is, but also why, this paper introduces and proposes, as an invitation to further transdisciplinary discussion and investigation, a framing and narrative that offers societal, economic and cultural opportunities to consciously usher in our next and evolutionary steps as a species.

As we enter the decade of the IDSSD, this discussion paper posits that we are now able to support and help synergise our collective efforts underpinned and framed by an emergent unitive perspective that recognises we are mutually interdependent with each other, our planetary home and the whole world.

Far more that a revolution in science — and recalling, as Donella Meadows, co-author of the Club of Rome's *The Limits to Growth* report, maintained — such a change of mindset may offer the most effective intervention we can offer to guide and empower democratic and equitable responses to existential risks and the paths to the regenerative and sustainable future that the IDSSD envisions.

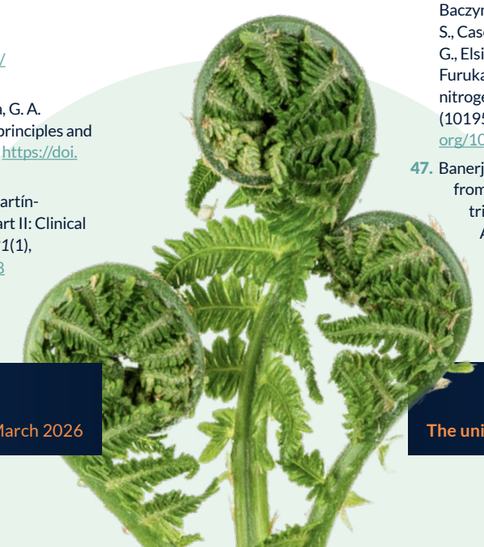
References:

1. Shrivastava, P., Álvarez Pereira, C., & Mairlot, L. (2025). *Planetary peace for human security: Responses to existential risks in the Anthropocene*. The Club of Rome. https://www.clubofrome.org/wp-content/uploads/2025/08/CoR-Planetary_Peace_Paper_CLEAN.pdf
2. NOVA. (2023, May 19). *An atom is 99.99999999999% empty space* [Video]. Facebook. https://www.facebook.com/NOVApbs/videos/what-does-an-atom-really-look-like/3455688008039553/
3. Cox, B., & Forshaw, J. (2010). *Why does E=mc2 (and why should we care?)*. Da Capo Press.
4. Sobral, D., Small, I., Best, P. N., Geach, J. E., Matsuda, Y., Stott, J. P., Cirasuolo, M., & Kurk, J. (2012). A large Hα survey at z=2.23, 1.47, 0.84 & 0.40: The 11 Gyr evolution of star-forming galaxies from HiZELS. *Monthly Notices of the Royal Astronomical Society, 428*(2), 1128–1146. https://doi.org/10.48550/arXiv.1202.3436
5. Currivan, J. (2017). *The cosmic hologram: In-formation at the center of creation*. Inner Traditions.
6. Currivan, J. (2022). *The story of Gaia: The big breath and the evolutionary journey of our conscious planet*. Inner Traditions.
7. Bérut, A., Arakelyan, A., Petrosyan, A., Ciliberto, S., Dillenschneider, R., & Lutz, E. (2012). Experimental verification of Landauer's principle linking information and thermodynamics. *Nature, 483*, 187–189. https://doi.org/10.1038/nature10872
8. Rauch, D., Handsteiner, J., Hochrainer, A., Gallicchio, J., Friedman, A. S., Leung, C., Liu, B., Bulla, L., Ecker, S., Steinlechner, F., Ursin, R., Hu, B., Leon, D., Benn, C., Ghedina, A., Cecconi, M., Huth., A. H., Kaiser, D. I., Scheidl, T., & Zeilinger, A. (2018). Cosmic bell test using random measurement settings from high-redshift quasars. *Physical Review Letters, 121*(8), Article 080403. https://doi.org/10.1103/PhysRevLett.121.080403
9. Ananthaswamy, A. (2023, March 1). *Is our universe a hologram? Physicists debate famous idea on its 25th anniversary*. Scientific American. https://www.scientificamerican.com/article/is-our-universe-a-hologram-physicists-debate-famous-idea-on-its-25th-anniversary1/
10. Afshordi, N., Corianò, C., Delle Rose, L., Gould, E., & Skenderis, K. (2017). From Planck data to Planck era: Observational tests of holographic cosmology. *Physical Review Letters, 118*, Article 041301. https://doi.org/10.1103/PhysRevLett.118.041301
11. Dacey, J. (2010, February 9). *Fractal patterns spotted in the quantum realm*. Physics World. http://physicsworld.com/cws/article/news/2010/feb/09/fractal-patterns-spotted-in-the-quantum-realm
12. Costa, J. M., Sagués, F., & Vilarrasa, M. (1991). Fractal patterns from corrosion pitting. *Corrosion Science, 32*(5–6), 665–668. https://doi.org/10.1016/0010-938X(91)90114-5
13. Mandelbrot, B. (1975). Stochastic models for the Earth's relief, the shape and the fractal dimension of the coastlines, and the number-area rule for islands. *PNAS, 72*(10), 3825–3828. https://doi.org/10.1073/pnas.72.10.3825
14. Madhyshani, K., & Sonnadara, U. J. (2012). Fractal analysis of cloud shapes. *Proceedings of the IPSL Technical Sessions, 28*, 59–64. https://www.semanticscholar.org/paper/Fractal-Analysis-of-Cloud-Shapes-Madhushani-Sonnadara/f94c6b5c3727c2b6043b14b22bd092e2cc29e325?p2df
15. Demydenko, O. (2017). Fractal analysis of climatic parameters and productivity of cereal crops. *Visnyk agrarnoi nauky, 95*(7), 10–16. https://www.researchgate.net/publication/329361860_Fractal_analysis_of_climatic_parameters_and_productivity_of_cereal_crops
16. Turcotte, D. L. (1991). Fractals in geology: What are they and what are they good for? *GSA Today, 1*(1), 1–4. https://rock.geosociety.org/net/gsatoday/archive/1/1/pdf/i1052-5173-1-1-sci.pdf
17. Warwick University. (2007, May 24). *Astrophysicists find fractal image of Sun's 'storm season' imprinted on solar wind* [Press release]. www.warwick.ac.uk/newsandevents/pressreleases/astrophysicists_find_fractal
18. International Centre for Radio Astronomy Research. (2012, September 17). *WiggleZ confirms the big picture of the universe*. https://www.icrar.org/wigglez-confirms-big-picture-universe/
19. Mandelbrot, B. B., & Hudson, R. L. (2008). *The mis(behaviour) of markets: A fractal view of risk, ruin and reward*. Profile Books.
20. Willinger, W., & Paxson, V. (1998). Where mathematics meets the internet. *Notices of the American Mathematical Society, 45*(8), 961–970. https://www.ams.org/notices/199808/paxson.pdf
21. Albert, R., Jeong, H., & Barabási, A-L. (1999). Diameter of the World-Wide Web. *Nature, 401*(6749), 130–131. https://doi.org/10.1038/43601
22. Faloutsos, M., Faloutsos, P., & Faloutsos, C. (1999). On power-law relationships of the Internet topology. *ACM SIGCOMM Computer Communication Review, 29*(4), 251–262. https://doi.org/10.1145/316194.316229
23. Barabási, A-L., & Oliveira, J. G. (2005). Darwin and Einstein correspondence patterns. *Nature, 437*(1251). https://doi.org/10.1038/4371251a
24. Dezsö, Z., Almaas, E., Lukács, A., Rácz, B., Szakadát, I., & Barabási, A-L. (2006). Dynamics of information access on the web. *Physical Review E, 73*, Article 066132. https://doi.org/10.1103/PhysRevE.73.066132
25. Rybski, D., Buldyrev, S. V., Havlin, S., Liljeros, F., & Makse, H. A. (2009). Scaling laws of human interaction activity. *PNAS, 106*(31), 12640–12645. https://doi.org/10.1073/pnas.0902667106
26. Song, C., Qu, Z., Blumm, N., & Barabási, A-L. (2010). Limits of predictability in human mobility. *Science, 327*(5968), 1018–1021. https://doi.org/10.1126/science.1177170
27. Emerging Technology from the arXiv. (2015, January 16). *Astrophysicists prove that cities on Earth grow in the same way as galaxies in space*. MIT Technology Review. https://www.technologyreview.com/2015/01/16/11869/astrophysicists-prove-that-cities-on-earth-grow-in-the-same-way-as-galaxies-in-space/
28. Richardson, L. F. (1948). Variation of the frequency of fatal quarrels with magnitude. *Journal of the American Statistical Association, 43*(244), 523–546. https://doi.org/10.2307/2280704
29. Richardson, L. F. (1984). *Statistics of deadly quarrels, 1809–1949*. ICPSR. https://doi.org/10.3886/ICPSR05407.v1
30. Miami University. (2011, July 14). *Predicting insurgent attacks* [Press release]. https://www.sciencedaily.com/releases/2009/12/091217150845.htm
31. Di Ieva, A., Grizzi, F., Jelinek, H., Pellionisz, A. J., & Losa, G. A. (2014). Fractals in the neurosciences, part I: General principles and basic neurosciences. *Neuroscientist, 20*(40), 403–417. https://doi.org/10.1177/1073858413513927
32. Di Ieva, A., Esteban, F. J., Grizzi, F., Klonowski, W., & Martín-Landrove, M. (2015). Fractals in the neurosciences, part II: Clinical applications and future perspectives. *Neuroscientist, 21*(1), 30–43. https://doi.org/10.1177/1073858413513928
33. Walach, H. (2019). *Galileo Commission report: Beyond a materialist worldview: Towards an expanded science*. The Scientific and Medical Network. https://galileocommission.org/report/
34. Vedral, V. (2010). *Decoding reality: The universe as quantum information*. Oxford University Press.
35. Greene, B. (2004). *The fabric of the cosmos: Space, time, and the texture of reality*. Vintage.
36. Jacobson, T. (1995). Thermodynamics of spacetime: The Einstein equation of state. *Physical Review Letters, 75*, 1260–1263. https://doi.org/10.48550/arXiv.gr-qc/9504004.

    Kyodo News. (2022, June 6). *Amino acids found in asteroid samples collected by Japan's Hayabusa2 probe*. https://english.kyodonews.net/news/2022/06/9a7dbced6c3a-amino-acids-found-in-asteroid-samples-collected-by-hayabusa2-probe.html
37. Verlinde, E. P. (2011). On the origin of gravity and the laws of Newton. *Journal of High Energy Physics, 2011*, Article 9. https://doi.org/10.48550/arXiv.1001.0785
38. Wang, T. (2012). Modified entropic gravity revisited. *Science China Physics, Mechanics & Astronomy, 57*, 1623–1629. https://doi.org/10.48550/arXiv.1211.5722
39. Torday, J. S. (2022). Consciousness, embodied quantum entanglement. *Progress in Biophysics and Molecular Biology, 177*, 125–128. https://doi.org/10.1016/j.pbiomolbio.2022.11.002
40. Purevdorj-Gage, L. B., Sheehan, K. B., Hyman, L. E. (2006). Effects of low-shear modeled microgravity on cell function, gene expression, and phenotype in Saccharomyces cerevisiae. *Applied and Environmental Microbiology, 72*(7), 4569–4575. https://doi.org/10.1128/AEM.03050-05
41. McGuire, B. A., Burkhardt, A. M., Kalenskii, S., Shingledecker, C. N., Remijan, A. J., Herbst, E., & McCarthy, M. C. (2018). Detection of the aromatic molecule benzonitrile (c-C_6H_5CN) in the interstellar medium. *Science, 359*(6372), 202–205. https://doi.org/10.1126/science.aao4890
42. SpaceRef. (2020, June 17). *New organic molecule discovered in an interstellar cloud* [Press release]. Space News. https://spacenews.com/new-organic-molecule-discovered-in-an-interstellar-cloud/
43. Oba, Y., Takano, Y., Naraoka, H., Watanabe, N., & Kouchi, A. (2019). Nucleobase synthesis in interstellar ices. *Nature Communications, 10*, Article 4413. https://doi.org/10.1038/s41467-019-12404-1
44. Ioppolo, S., Fedoseev, G., Chuang, K-J., Cuppen, H. M., Clements, A. R., Jin, M., Garrod, R. T., Qasim, D., Kofman, V., van Dishoeck, E. F., & Linnartz, H. (2020). A non-energetic mechanism for glycine formation in the interstellar medium. Nature Astronomy, 5, 197–205. https://doi.org/10.1038/s41550-020-01249-0
45. National Radio Astronomy Observatory. (2000, June 20). Scientists discover sugar in space [Press release]. https://ui.adsabs.harvard.edu/abs/2000nrao.pres...13./abstract
46. Glavin, D. P., Dworkin, J. P., Alexander, C. M. O'D., Aponte, J. C., Baczynski, A. A., Barnes, J. J., Betchel, H. A., Berger, E. L., Burton, A. S., Caselli, P., Chung, A. H., Clemett, S. J., Cody, G. D., Dominguez, G., Elsila, J. E., Farnsworth, K. K., Foustoukos, D. I., Freeman, K. H., Furukawa, Y., … Lauretta, D. S. (2025). Abundant ammonia and nitrogen-rich soluble organic matter in samples from asteroid (101955) Bennu. *Nature Astronomy, 9*, 199–210. https://doi.org/10.1038/s41550-024-02472-9
47. Banerjee, P., Qian, Y-Z., Heger, A., & Haxton, W. C. (2016). Evidence from stable isotopes and 10Be for solar system formation triggered by a low-mass supernova. *Nature Communications, 7*, Article 13639. https://doi.org/10.1038/ncomms13639
48. Narayanan, S. A. (2023). Gravity's effect on biology. *Frontiers in Physiology, 14*, Article 1199175. https://doi.org/10.3389/fphys.2023.1199175
49. Thorne, S. (2021). Modeling the role of gravitation in metabolic processes. *Communicative & Integrative Biology, 14*(1), 115–135. https://doi.org/10.1080/19420889.2021.1914913
50. Hariom, S. K, Ravi, A., Mohan, G. R., Pochiraju, H. D., Chattopadhyay, S., & Nelson, E. J. R. (2021). Animal physiology across the gravity continuum. *Acta Astronautica, 178*, 522–535. https://doi.org/10.1016/j.actaastro.2020.09.044
51. Spiegel, D. S., Raymond, S. N., Dressing, C. D., Scharf, C. A., & Mitchell, J. L. (2010). Generalized Milankovitch cycles and long-term climate habitability. *The Astrophysical Journal, 721*(2), 1308–1318. https://doi.org/10.1088/0004-637X/721/2/1308
52. Freeland, S. J., & Hurst, L. D. (1998). The genetic code is one in a million. *Journal of Molecular Evolution, 47*, 238–248. https://doi.org/10.1007/PL00006381
53. Le Vay, K., & Mutschler, H. (2020). How DNA and RNA subunits might have formed to make the first genetic alphabet. *Nature, 582*(7810), 33–34. https://doi.org/10.1038/d41586-020-01566-4
54. Doig, A. J. (2016). Frozen, but no accident – why the 20 standard amino acids were selected. *The FEBS Journal, 284*(9), 1296–1305. https://doi.org/10.1111/febs.13982
55. Lieberman-Aiden, E., van Berkum, N. L., Williams, L., Imakaev, M., Ragoczy, T., Telling, A., Amit, A., Lajoie, B. R., Sabo, P. J., Dorschner, M. O., Sandstrom, R., Bernstein, B., Bender, M. A., Groudine, M., Gnirke, A., Stamatoyannapoulos, J., Mirny, L. A., Lander, E. S., & Dekker, J. (2009). Comprehensive mapping of long-range interactions reveals folding principles of the human genome. *Science, 326*(5950), 289–293. https://doi.org/10.1126/science.1181369
56. Radzicka, A., & Wolfenden, R. (1995). A proficient enzyme. *Science, 267*(5194), 90–93. https://doi.org/10.1126/science.7809611
57. Pawluk, A. (2017). Tiny answers to big questions. *Cell, 170*(2), 215–17. https://doi.org/10.1016/j.cell.2017.06.033
58. Obeng, N., Pratama, A. A., & van Elsas, J. D. (2016). The significance of mutualistic phages for bacterial ecology and evolution. *Trends in Microbiology, 24*(6), 440–449. https://doi.org/10.1016/j.tim.2015.12.009
59. Battail, G. (2019). Error-correcting codes and information in biology. *Biosystems, 184*, Article 103987. https://doi.org/10.1016/j.biosystems.2019.103987
60. Torres-Sosa, C., Huang, S., & Aldana, M. (2012). Criticality is an emergent property of genetic networks that exhibit evolvability. *PLOS Computational Biology 8*(9), Article e1002669. https://doi.org/10.1371/journal.pcbi.1002669
61. Boedecker, J., Obst, O., Lizier, J. T., Mayer, N. M., & Asada, M. (2012). Information processing in echo state networks at the edge of chaos. *Theory in Biosciences, 131*, 205–213. https://doi.org/10.1007/s12064-011-0146-8
62. Gisiger, T. (2007). Scale invariance in biology: Coincidence or footprint of a universal mechanism? *Biological Reviews, 76*(2), 161–209. https://doi.org/10.1017/S1464793101005607
63. Currivan, J., Mahmoud, Y., & Story, G. (2024, December 19). *How to be a good ancestor in support of the UN Declaration on Future Generations*. IPI Global Observatory. https://theglobalobservatory.org/2024/12/how-to-be-a-good-ancestor-in-support-of-the-un-declaration-on-future-generations/









the fifth element

The Fifth Element is a platform for systems transformation. It creates the conditions for people, initiatives and institutions to converge, learn and act together toward global equity on a healthy planet. Rather than leading with a fixed agenda, it nurtures collaboration, supports shared sensemaking and helps connect diverse efforts into a larger, more coherent field of change.

www.thefifthelement.earth

linkedin.com/company/the-fifth-element-earth

instagram.com/_the.fifth.element/

chat.whatsapp.com

This work is licensed under a Creative Commons Atrribution-NonCommercial 4.0 International License.
For any commercial use please contact info@clubofrome.org.

