

## The Phases of Matter

John A. Gowan

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(See: R. B. Laughlin *A Different Universe* Basic Books 2005)

In this deeply thoughtful, informative, and rewarding book, Laughlin, a physics Nobel laureate (1998), discusses the emergence of natural law from organizational/collective principles in nature and in various phases of matter - as in (among many other and more exotic examples) the familiar shift from the laws of crystalline order to those of hydrodynamics and finally to the gas laws, as ice melts to water and water evaporates to vapor. He is at pains to point out that most of the phenomena in our daily lives are produced by the higher-level emergent principles and laws of phase organization due to the collective action of vast myriads of atomic constituents whose individual properties count for very little in the final social milieu - and not just because an individual atom is only one among many, but because totally different organizational principles are at work in the different phases of bulk matter, in contrast to those operating between small numbers of individual particles: for example, the quantum behavior of atoms vs the Newtonian behavior of bowling balls. Laughlin raises the question: which laws are the more fundamental - the quantum laws of the individual atoms, or the emergent laws of the collective? Although he identifies this as a semantic distinction that cannot be definitively answered, as a practical matter of survival (in biology), he comes down in favor of the collective.

The work of this [web page in General Systems](#) and the [fractal organization of nature](#) has concerned itself with just such hierarchical levels of organization (hence Laughlin's book is very much to my taste), although the language and concepts of phase shifts as used in the physical sciences has not generally been employed. My professional training has been mostly in biology where concepts of hierarchical levels of organization with attendant emergent phenomena are nothing less than the foundation of the science - from the cellular structure of all large organisms to the evolutionary "Tree of Life", and the biochemical underpinnings of metabolism, reproduction, development, and perception. Unifying the sciences through a common taxonomy and terminology is a major goal of General Systems; consequently, I have taken another look at the fractal organization of the "General Systems" webpage, using the language of phase shifts and their emergent organizational principles as suggested by Laughlin's book.

A *phase* is a self-organizing stable or semi-stable state of energy/matter/information whose *emergent* properties are unique to its level of organization, characteristic of the collective action of its parts and not of the properties of the parts themselves. For example, in the biological information hierarchy that applies to our own human level of organization: Individual, Family, Society, Species - biochemical metabolism is a characteristic of the individual; reproduction is a characteristic of families; civilization is a characteristic of societies; genetic (Darwinian) evolution is a characteristic of species. Phase transitions exhibit the emergence of collective laws and behaviors that are both qualitatively distinct and unpredictable from the laws and behaviors of lower organizational levels within the collective. Life is an *information phase* of matter; our Universe is a life-friendly *anthropic phase* of the Multiverse. (See: "[The Information Pathway](#)"; "[The Information Ladder](#)"; "[The Fractal Organization of Nature](#)".) Below I list various phases of matter discussed on this website, with links to relevant papers. I have grouped the phases according to their origin in a particular force (as in one of the "four forces of physics"), or according to their common origin in some other analogous force or

agency (as in biology).

A semantic question arises where to draw the line defining phases. Clearly, life itself is an information phase of matter. There are many taxonomic subdivisions of living forms - bacteria, fungi, plants, animals, dinosaurs, mammals, individual species - etc. Should we designate any of these as phases in their own right - or simply leave them as we find them in the biological sciences, distinct subdivisions within a single overarching life phase? Similarly, are the different chemical and mineral "species" different phases of matter - or only distinct subdivisions of matter's single solid state phase? In order to keep the taxonomy simple, I will adopt a conservative view and consider all living forms as members and examples of a single phase of matter - the information, biological, or life phase of matter. The taxonomic subdivisions of biology will remain just as they are - recognizable subdivisions of the main life phase, and similarly for the mineral and chemical "species" of the abiotic chemical realm - we will treat them as distinct members and examples of the single solid phase of matter - sub-phases rather than phases in and of themselves. The elements of the Periodic Table are likewise seen as distinct sub-members of the atomic phase of matter (when considered as single, individual atoms).

**1) Force unification transitions, or phase shifts between primordial symmetric energy states:** (A postulated series or "cascade" of transitions between unified force symmetric energy states or phases (at very high energy), leading from the "Big Bang" or "Creation Event" to our ordinary electromagnetic (EM) "ground state" of matter, as the Universe expands and cools). The four forces separate from one another sequentially (beginning with gravity) as the cascade descends to the EM "ground state":

1a) **TOE** (theory of everything): All forces (including gravity) unified; fermions unified with bosons. ("Ylem", quark-gluon "soup") ("Y" IVBs and associated Higgs scalar boson?)

1b) **GUT** (grand unified theory): Electroweak and strong forces unified; leptons unified with quarks - "leptoquarks"; fermions unified among themselves, but bosons (including gravity) separate from fermions. ("X" IVBs and associated Higgs scalar boson?)

1c) **EW** (electroweak unification): Leptons unified with other leptons, and quarks unified with other quarks, but leptons separate from quarks.  $W^+$ ,  $W^-$ ,  $Z$  Intermediate Vector Bosons and associated Higgs scalar boson.

1d) **EM** (electromagnetic unification): Ground state of cold, bound, electromagnetic matter (atoms)); electric and magnetic forces unified (photons). All forces separate. (See: "[Table of the Higgs Cascade](#)"; "[The Higgs Boson and the Weak Force IVBs](#)".)

**2) Weak force phases of matter:** including IVBs ( $W$  and  $Z$  Intermediate Vector Bosons and their presumed heavier analogs), Higgs bosons (a hierarchy of several species?), neutrinos (3 or 4 types - neutrinos carry the explicit form of [weak force "identity" charge](#)). Except for the TOE, the unified-force symmetric energy states are all created by the weak force during the "Big Bang". All (except the TOE) are asymmetric, temporal, bound energy (massive) energy states lacking intrinsic motion "c" and lacking the symmetric complement of antimatter, an asymmetry which requires them to carry various charges, including gravity. [Noether's Theorem](#) implies that [the charges of matter are symmetry debts of light](#). (See: "[The 'W' IVB and the Weak Force Mechanism](#)"; "[The Higgs Boson and](#)

[the Weak Force IVBs](#)"; ["Introduction to the Weak Force"](#).) The weak force is responsible for the asymmetric creation of matter during the "Big Bang", radioactive and particle decay, and transformations of identity in *single* elementary particles. (See also: ["The Origin of Matter and Information"](#).)

**3) Strong force phases of matter:** atomic nuclei of the Periodic Table - protons, neutrons, "nucleons" (superpositions); quarks (6 "flavors" x 3 "colors"); gluons (8 color x anticolor combinations). (See: ["The Strong Force: Two expressions"](#).) Until humans discovered radioactivity and created nuclear bombs and technology, the nuclear phase of atomic matter operated entirely beneath our notice, buried deep in the solar interior or beneath the electron shells of atoms. We knew only sunlight and chemistry. The tremendous primordial energy of the naked atomic nucleus has proved to be an actual "Pandora's Box". Hopefully, the same will not become true of DNA, likewise buried (until recent genetic technology) beneath our notice deep within the nuclei of cells and gametes. We knew only sex and the variety of Nature. Apparently we explore below or above the protective barriers of our native phase at our own considerable peril. "A little knowledge is a dangerous thing."

**4) Electromagnetic phases of matter:** The electromagnetic (EM) ground state of light and cold atomic matter (including the biotic and abiotic constituents of planet Earth).

The "vacuum" of space is created and gauged by the intrinsic motion of light as an entropic/energetic conservation domain for free electromagnetic energy. The Dirac/Heisenberg "vacuum" is the most symmetric phase of matter, composed of equal parts of matter and antimatter ("virtual" particles). By its own "intrinsic" (entropic) motion, light produces space, and "velocity c" (the electromagnetic constant) acts as the symmetry gauge of space and the electromagnetic metric of free energy - vanishing mass, charge, time, and gravity. By Noether's Theorem, this symmetric phase of energy must be conserved, including the non-local symmetric attributes of light. The "quality" of light's energy no less than its quantity must be conserved. This is the fundamental basis of the Unified Field Theory: *The charges of matter are symmetry debts of light*. Space is the entropic and energy-conserving domain of free electromagnetic energy - produced by the "intrinsic" (entropic) motion of light acting in its own interest to conserve and regulate its own energy.

Antimatter, magnetic and electric fields, currents, and related phenomena, light; chemical elements of the Periodic Table - all may be considered phases of electromagnetic energy. Matter is an asymmetric form of bound electromagnetic energy, lacking antimatter, presumed to have been created during the "Big Bang" via the asymmetric weak-force decay of electrically neutral leptoquarks. (See: ["The Origin of Matter and Information"](#).) Common material phases of matter: solids, liquids, gases. Cold temperature phases include superconductivity and superfluids. High temperature phases include plasmas (ionized gas). Life is the most highly complex and organized (and the only self-interested) *information phase* of matter and the EM realm.

The reason the vacuum does not produce a gravitational field is for the [same reason that light does not](#) - its massless energy is distributed everywhere simultaneously, that is, perfectly symmetrically. Since gravity is a *symmetry debt* recording the asymmetric spacetime distribution of localized massive immobile forms of bound electromagnetic energy (particles, atoms, matter, mass), neither freely moving light nor the symmetric, massless vacuum carries a gravitational charge or produces a

gravitational field. (See: "[A Rational for Gravity](#)".)

The "metric" of spacetime, as gauged by the universal electromagnetic constant "c" and modified by the universal gravitational constant "G" is a scaling property of the "vacuum" as required by energy conservation. In function, it is analogous to the Higgs boson which scales the bound energy realm.

**4a) Information and biological phases of matter:** Life forms, genetic information coded in molecular DNA/RNA; abstract/symbolic forms of information invented by brains and especially humans, including such emergent phenomena as consciousness, language, creative arts, science, mathematics, communications and information technology, etc. Mental life (abstracted perception) is an emergent property of the collective action of massively interconnected neurons of large brains. In humans (only), creative (imaginary) mental life can be transformed through language, manual dexterity, and social organization/technology into material reality. An automobile or an airplane is an example of an individual's creative imagination translated to physical reality by the collective action of human technological society. Biological taxa (individual species - manifestations or productions of biological (DNA/RNA) information) are considered as distinct types or examples of the life phase, that is, as sub-phases of biology, much as the distinct mineral and molecular species of chemistry are considered as sub-phases of abiotic matter. Life exists in the narrow temperature band in which water is in its liquid phase: 0 - 100 degrees centigrade. Because this temperature is very near the bottom of the absolute temperature scale, there is an obvious analogy between living processes in the information realm and superconducting processes in the material realm. Life - and especially mental life - appears to be some sort of superconducting liquid crystal of integrated information elements (DNA, proteins, cells, neurons, etc.).

The death of an individual is equivalent to a phase shift from physical to spiritual - an abrupt and complete change of organizational law and principle. The "spirit world" is thus a postulated phase of the living world, much as the "vacuum" with its virtual particles is a perfectly symmetric (and hence unmanifest) phase of the material world. We may also view death as a phase shift from the specific to the general, that is (for example), as a retreat from our own specifically realized genetic combination, to the more generic information content of the human genome from which we originated. When we die, the genetic information that created us will still reside in generic form within the living genome of the human species, and indeed, even within life generally. There is a parallel retreat (at death) from existence in specific present time to existence only in generalized historical time. (See: "[The Fractal Organization of Nature](#)"; see also: "[The Human Connection](#)".)

**5) Gravitational (astronomical, cosmological) phases of matter:** Planetary (spherical shape); stellar (plasma, nucleosynthetic); white dwarf (electron shells collapsed into an "electron sea"); neutron star ("electron sea" forced into protons to produce neutrons and an astronomically-sized atomic nucleus); black hole (4-D electromagnetic metric collapses into 2-D gravitational metric (the "event horizon") at  $g = c$ , where time completely replaces space. A black hole is the final or pure phase of temporal entropy for matter). Cosmological gravitational phases include orbital systems such as galaxies and solar systems, and the universe at large: historic spacetime. The universe creates galaxies; galaxies create stars; stars create heavy elements and planetary systems; planetary systems create life. Other possible cosmological phases include "inflation" and the "Multiverse". (See: "[Table of the Higgs Cascade](#)"; "[Why There are 3 Spatial Dimensions](#)"; "[The Destruction of Information](#)"; "[A Rationale for](#)

[Gravity](#)". See also: "[A Spacetime Map of the Universe](#)".)

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Humans are in the middle range of a [huge hierarchy of material organizational levels](#), both biotic and abiotic. For the most part, like the animals, we are largely or completely unaware of the activity occurring within the levels either above or below us, and we can do little or nothing to effect, change, or control them. (This is where religion and the gods are invoked for help.) We don't know (or need to know) how we digest our food, nor how our body grows and develops. And we are largely unaware of these processes as they take place - they just happen. There is a huge range of biochemical processes from the cell on up to our complete organism that goes on without our knowledge or awareness, including, among other functions, the distribution of energy and oxygen throughout our body for the maintenance of our life processes. Other than the sex act itself, the whole process of reproduction, growth, and development goes on whether we understand it or not, including the mysterious mechanism of inheritance. The entire hierarchy of biochemistry, cells, organs, tissues, etc., is itself founded upon an abiotic hierarchy of molecules, atoms, subatomic particles, and quantum mechanical processes of which we are even less aware. Not only am I a huge collection and hierarchy of correlated biochemical processes, organelles, symbionts, cells, specialized organs and tissues, but it even turns out that I am a huge collection of microbial species; there are more cells of other species (mostly beneficial and necessary) within me than there are of my own.

Nor is the situation any better concerning the organizational levels above humans. Processes such as evolution and the bio-geo-chemical cycles of the earth proceed without our knowledge. Weather and climate are beyond our control; likewise glacial periods, plate tectonics, mountain building, vulcanism, and earthquakes. The solar system rolls on without our permission, and until recently, without our understanding; meteors and comets bombard the earth; the earth's magnetic field protects us from the sun's local outbursts, but it cannot protect us from the life cycle of our dying star, nor the eventual and inevitable collision between our galaxy and our giant neighbor Andromeda. The great Milky Way galaxy of which we are a part was entirely unknown only a century ago, much less its function in the production of heavy elements, stars, and their planetary systems. The list of our blissful ignorance can be extended both up and down the hierarchy, and in fact we don't know how far it extends in either direction or what it includes (the Multiverse? Strings? Heaven? Hell? A Realm of Natural Law and abstract Ideal Forms? Spiritual dimensions?).

We can, like the animals, live comfortably within our own biological level of organization without ever giving a thought to the functioning of all those complex levels both above and below us, both within and without, biotic and abiotic, material or abstract, physical or spiritual, earthly or cosmic, even though all are necessary for our survival and the coordinated functioning and conservation of the universe as a whole. The social/political/legal/economic functioning of our own collective organizational level (society/civilization) is only barely within our grasp. Nevertheless, it is the unique destiny of humanity to be the "eyes and ears" of the universe. The universe comes to understand itself and continue its growth through life and curious intelligent beings like ourselves; we are the self-awareness of the universe. It is the human role to probe the organizational structures both above and below our own with our space programs and atom smashers, telescopes and microscopes, mathematics and technology, to understand them and see how we fit into the Great Collective of the Cosmos, both its material hierarchies and its temporal cycles, its evolution, and even its purposes.

When we look up at the stars at night, we see directly into the grander organizational structures of our Cosmos (solar system/galaxy/universe), far above our biological phase both literally and figuratively, which we are only just beginning to understand. The cold glitter of the stars and the vastness of the night sky can be frightening as well as magnificent and intriguing. We should remember that our own life-giving Sun is a normal member of this awesome assembly, and so affords us a friendly entrance and introduction into its mysteries.

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Our own level of organization within the biotic or life phase of matter is the "[Species](#)" level. This level is itself divided into four sections of collective organizational complexity: 1) the Individual (or metabolic) level; 2) the Family (or reproductive) level; 3) the Social (or political/legal/civil) level; 4) the Species (or evolutionary) level. One of the astonishing aspects of the individual level is the discovery that we are not even a complete organism, and that our gender opposite is running around as another free individual, who must be scouted out and acquired, generally through some kind of courtship, trial, test, contract, or even purchase. We must prove ourselves worthy to reproduce. Marriage is a preliminary step toward the complex legal structure of society, the next organizational level above the family. In most respects society exists to safeguard the vital reproductive function of the family. At the social level of civilization, we also find the emergent phenomena of technology, the sciences, the arts, religion, as well as legal and political structures, including the military, legislative bodies, a constitution, national boundaries, etc. The final "Species" organizational level (defined as the closed genome of humanity) exists in evolutionary time, may have no particular geographic boundary, is responsible for gender divisions of the individual and family levels, and has its own agenda, as Darwin pointed out ("survival of the fittest"), and as we are still discovering ("the selfish gene", "group selection", "epigenetics", etc.).

Each species must find its own unique niche, its particular way of "making a living" (surviving) in the world among myriad other species, who are all trying their best to do the same. The human niche has evolved from a small, local group of anthropoid social, bipedal, intelligent hunter-gatherers with language and fire, using hand-crafted and hand-held tools, to an enormously populous, world-wide species of many social groupings, languages, and nationalities, whose principle and unique niche is that of the *social apprehension and application of natural law*, including agriculture, medicine, science, and all modern technology. In a stunning demonstration of the fractal organization of nature, we have even appropriated the evolutionary genetic mechanism, laid hands upon the atomic nucleus, duplicated the solar process of element-making, and are now beginning our journey into the galaxy which spawned us.

### **Links:**

#### **Gravitation**

[Section II: Introduction to Gravitation](#)

[Why Gravity? A Rationale for Gravitation](#)

[A Description of Gravitation](#)

[The Double Conservation Role of Gravitation: Entropy vs Symmetry](#)

[Extending Einstein's "Equivalence Principle"](#)

[The Conversion of Space to Time](#)

["Dark Energy" and the "Accelerating Universe": Does Light Produce a Gravitational field?](#)

## Entropy

[Section VII: Introduction to Entropy](#)

[Entropy, Gravitation, and Thermodynamics: Part I; Part II](#)

[Spatial vs Temporal Entropy](#)

[The Intrinsic Motions of Time, Space, and Gravity](#)

[Currents of Symmetry and Entropy](#)

[The Time Train](#)

[Traveling Twin Paradox: Covariance of Space and Time](#)

[The Half-life of Proton Decay and the 'Heat Death' of the Cosmos](#)

## The Fractal Organization of Nature

[Section III: Introduction to Fractals](#)

[The Fractal Organization of Nature](#) (table)

[Part 1: Microphysical Realm](#)

[Part 2: Biophysical Realm](#)

[Part 3: Astrophysical Realm](#)

[Part 4: Metaphysical Realm - Intuitive Mode](#)

[Part 5: Metaphysical Realm - Rational Mode](#)

[Part6: The Fractal Organization of Nature \(summary\)](#) (text)

[Newton and Darwin: The Evolution and Abundance of Life in the Cosmos](#)

[Commentary on the Metaphysical Realm \(rational mode\)](#)

[The Human Connection](#)

## Information

[Section VI: Introduction to Information](#)

[Chardin: Prophet of the Information Age](#)

[Negentropic Information](#)

[The Information Pathway](#) (text)

[The Formation of Matter and the Origin of Information](#)

[Nature's Fractal Pathway](#)

[The Destruction of Information](#)

[The Information Ladder](#) (table)

## Weak Force, Intermediate Vector Bosons ("IVBs"); Strong Force

[Section IV: Introduction to the Weak Force](#)

[The "W" IVB and the Weak Force Mechanism](#)

[The Weak Force: Identity or Number Charge](#)

[The Weak Force "W" Particle as the Bridge Between Symmetric \(2-D\) and Asymmetric \(4-D\) Reality](#)

[The Strong and Weak Short-Range Particle Forces](#)

[Section XVIII: The Strong Force: Two Expressions](#)  
[Section XVI: Introduction to the Higgs Boson \(Part I\)](#)  
[The "Higgs" Boson and the Spacetime Metric](#)  
[The "Higgs" Boson and the Weak Force IVBs: Part I](#)  
[The Higgs Boson and the Evolutionary Eras of the Cosmos](#)  
[The Particle Table](#)

## **General Systems and Metaphysics**

[Section VIII: Introduction to General Systems, Complex Systems](#)  
[Synopsis of the "Tetrahedron Model" of the Unified Field Theory](#)  
[Spiritual and Scientific Principles of the Tetrahedron Cosmic Energy Model](#)  
[A General Systems Analysis of the Creative Process in Nature](#)  
[Section XII: Man's Role in Nature](#)  
[Section XIII: The Solar Archetype](#)  
[Is There Life After Death?](#)  
[The Grail and Hourglass Diagrams](#)  
[Human Life-Span Development General Systems 4x3 Models](#)  
[Stewart C. Dodd's 4x4 Mathematical General System Matrix](#)  
Books by my late father Prof. John Curtis Gowan  
["Trance, Art, Creativity" An Investigation of the Numinous Element and the Metaphysical Realm. A Book by Prof. John C. Gowan, Sr.](#)  
["Operations of Increasing Order" Further Investigations of the Numinous Element and the Metaphysical Realm. A Book by Prof. John C. Gowan, Sr.](#)  
["Development of the Psychedelic Individual". A Book by Prof. John C. Gowan, Sr.](#)  
["Development of the Creative Individual". A Book by Prof. John C. Gowan, Sr.](#)

## **E-Book:**

[Introduction to the E-Book](#)  
[General Systems and a "Theory of Everything": Essays on Physics and the Nature of Reality](#)