The Freedom Law

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Abstract

This article explains (strong) emergence in reductionist terms. Two laws predict the structure of reality from the smallest particles to consciousness. The *freedom law* predicts (in a reducible way) how and when new systems, life and even new matter will emerge and where reducibility ends. The *law of life*, that is Bejan's "constructal law," predicts how this life will evolve or die. If this being or system persists then it is either alive in the sense that it persists and evolves in its "design" while being a process, or it is dead in the sense of being "bricked" after having been alive. But 'to predict' is not 'to understand.' This article is about *understanding*. As an illustration and elaboration the laws are applied to heat and fluid flow examples, and to the emergence of consciousness.

Keywords: flow systems, causality, reductive freedom, emergence, life, consciousness

* This article presupposes your acceptance of Bejan's constructal law.
. For an article explaining both the constructal law and the freedom law see [1].
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1 Introduction

"*Emergence*" means "*coming* into existence".[2] Many arguments have been given that show *the existence* of emergence.[2–6] What lacks is a *causal* explanation of why "systems" *must* emerge and evolve. Such systems include consciousness, matter, thoughts and life.[1] That is what this paper provides.

This article assumes that you know and accept the constructal law formulated by Adrian Bejan:

> "For a finite-size system to persist in time (to live), it must evolve [freely] in such a way that it provides easier access to the imposed currents that flow through it".[7–9]

The constructal law is about *being* and *staying* in existence. The freedom law that I will formulate is about life *coming* into existence. Remark that the Latin word "Natura" literally refers to the same, being the continual rebirth of reality.[10, 7'22"]

What I call "*Reductive freedom*" is the freedom named in Bejan's constructal law. The term refers to cause and effect not being (fully) reducible to the parts that something consists of. My thinking started from a neural network design which I think has consciousness.[11, 12] The reductive freedom of my and nature's neural designs makes it possible for thoughts, perception, feelings and qualia to *live in* this neural network and thereby to form a new, conscious *being*.

1.1 To Predict is Not to Understand – Making Truth Alive

As René Thom said: "To predict is not to understand" ("Prédire n'est pas expliquer").[13, 14] To understand our theories we must empathize with the entities of the external world. Things have to live inside us.[14, p126] That is what I, as a kind of 'truth artist,' try to cause here with my words.

1.2 Law and Definition of Life

To me the "constructal law" is the "law of *life*." Thinking in terms of life I sometimes speak of "*beings*" and "*existences*" instead of "systems." An *existence* is the system as a thing, entity, object or "design." A *being* is the system as living and flowing; it consists of the 'states' of a system plus an 'arrow of time.' In English this may seem somewhat artificial, but in Dutch the terms are "*zijnde*" and "*zijn*." The distinction between "existence" and "being" is related to that of "object" and "subject." Often it does not matter which of the two terms you use.

Beings *die*. Biologically dead beings dissolve, but many *physically* dead beings are very persistent and fundamental to reality.

Speaking of "beings" I reformulate the constructal law into, what I call, the *Law of Life*:

"For a (finite) *existence* to persist (in time), thus to *live*, it (or its *being*) must evolve freely in such a way that it can handle what it encounters more easily."

From this I deduct my *Definition of Life*:

"Life is the (in time) persisting and freely evolving flow-system or being of a (finite) existence (or design) that can handle what it encounters ever more easily."

2 To Cause to Emerge...

2.1 Causation & Reductionism

Reductive freedom (and also the constructal law) is about causation. We live in a culture that is reductionist in theory but non-reductionist in practice. Reductionism is the belief that everything that happens in this world is (in the end) *caused by* the smallest particles and interactions between them. As a consequence the 'wholes' that are formed by such 'parts' or 'particles' are not thought to be 'really' *causative*. For instance, our consciousness is thought to be illusionary. And psychology may not even be considered to be a real science because in the end everything is caused by 'quarks and quanta.' That is absurd, so in practice we are non-reductionist.

But 'wholes' (consisting of particles) of course are systems! And generally *natural* systems are *living* systems. Therefore everything that the constructal law predicts will happen. The 'whole' will be a living being. Thus it will be (evolving but) *persistent*, and *thereby* it will provide reductive freedom.

2.2 Reductive Freedom

Contrary to reductionism I claim that 'smaller' particles often form a mechanism, system or being in which these particles are *subdued*. If you turn one gear in a clock then all gears turn with it and with that all the atoms, quarks and so on within them. Thus such a system or being is made such that a certain input leads (more or less) to a certain output. In other words; the system has a typical *behavior* or *possibilities*, i.e. its *persistence* as seen from the *outside*. On the outside it is of no importance how the system or being does this since there is no (or only incomplete) causation from 'within' the system. It is only (or at least partly) reactive – Ellis speaks of this as the "multiple realizability of higher level functions".[6] The exception to this are systems that have no input, such as clocks and 'ordinary' 'entropic' kinetics (think of temperature and Brownian motion), and maybe systems or beings that have a 'will' or 'mind' of their own, but such systems will be large and complex thus not causal from '*deeply* within' either.

Thus there exists *freedom of reductive causation* (!). In other words there are possibilities of behavior, and these *arise* and *evolve naturally* (!) in living (flow)-systems. I call this freedom "reductive freedom." This, I claim, is the freedom named in Bejan's constructal law. This idea should be easy to understand. But it is not because it overthrows many worldviews and conceptions.

Remark that the reductive freedom or possibilities are themselves reducible, but only as freedom or possibilities. So their 'status' is principally *un*predictable *from 'within'* this system or being. Here reducibility ends. So here reductionism ends too.

2.3 Examples of Reductive Freedom and Life

Some 'easy' examples of beings living 'in' or 'on' other beings because of reductive freedom provided by the latter...

- A computer is made such that software can control it. Here software 'lives' in hardware. Remark, however, that computer and software are both artificial and 'dead.' They need humans to evolve;
- Likewise a biological cell is made such that DNA can control it. Thus a biological cell *provides freedom* to *any* DNA. The cell is alive at an *ontogenetic* timescale. DNA is alive at a *phylogenetic* timescale. Inside a cell DNA is a kind of dead and hardly evolving. DNA lives as a 'gene-pool' where genes are *distributed* in a pool of cells belonging to a species that exchange DNA in their offspring. Remark that viruses may swap DNA between species;
- Your brain and body are (partly) made such that your thoughts can control them. Your thoughts, perception, consciousness and knowledge *live* in your brain.[12] They are alive at different evolutionary timescales. Knowing and consciousness *evolve* momentary. Knowledge and memory *evolve* over a lifetime, or even longer when it is passed on from generation to generation. Erwin Schrödinger formulated it as follows in 1944:

  "(i) My body functions as a pure mechanism according to the Laws of Nature. (ii) Yet I know, by incontrovertible direct experience, that I am directing its motions, of which I foresee the effects, that may be fateful and all-important, in which case I feel and take full responsibility for them. The only possible inference from these two facts is, I think, that I – I in the widest meaning of the word, that is to say, every conscious mind that has ever said or felt 'I'– am the person, if any, who controls the 'motion of the atoms' according to the Laws of Nature".[3, Epilogue]

2.4 Point of View – Imaginary Consciousness

It sometimes helps to think of a system as conscious even if it is not. Then we can 'look' to the world from the position of any system and, as Thom says, "get into the skin" of them and be able to "empathize" with them.[14, p 126]

By my definition *a conscious system can incorporate (or copy) other systems within itself (or within its knowledge), possibly including itself and then we call it self-conscious.*[12] Our whole conscious system is based on this. Then one may see that, while software, DNA or knowledge runs in hardware, 'they' hardly 'know' anything about this hardware. The hardware that they run in is 'invisible' or 'unconscious' to 'them' or 'from their *point of view*' in as far as it provides freedom.

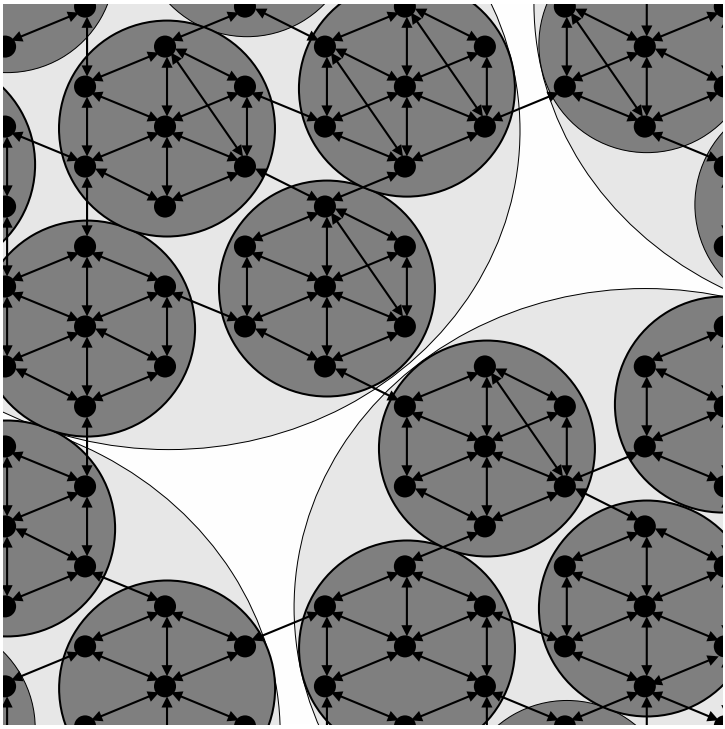

Figure 1 Freedom created by smaller particles (black circles) forming systems (gray circles) that accept 'their own' input and output. Light gray circles represent a next level. The arrows symbolize interaction (of any kind).

The other way around, to the hardware (i.e. the 'lower level' system) the software is not completely 'invisible' or 'unconscious.' For example, we can feel the forces of the social structure that we live in.

2.5 Intraverse and Extraverse

On the one hand reductive freedom is *caused* or *created* by a system, mechanism, being or life. On the other hand this reductive freedom *causes* or *creates* a new order, system, realm, being or life. The originating systems or beings, i.e. the systems causing the 'birth' of the new system, I call its "*intraverse*." The new system or being is the *extraverse* of these originating systems. These extraverses may again create a new extraverse. All these I consider to be part of the first extraverse. Equally an intraverse of an intraverse is part of an intraverse. Remark that 'the world turns around' the system you attend to. Intraverse and extraverse are *relative* terms. This is both how the real world and your consciousness works, but not how language and theories work. Consciousness is well adapted to reality. Truth is difficult.

In Figure 1 an intraverse could consist of a system of interconnected black circles, and then the extraverse could be (a system *in*) a light gray circle

– remark that in real world examples circles will not be as equal as in this simplified image.

Thus reductive freedom creates a distinction between an intraverse and an extraverse. The intraverse as a system creates and causes reductive freedom, i.e. possibilities of 'behavior.' Thus the created *freedom* is itself reducible *from an observer's point of view*. Yet exactly through that freedom the intraverse makes itself 'invisible' or 'unconscious' in its extraverse (if this extraverse would have self-consciousness). In the extraverse only its reductively free possibilities of behavior exist. Thus in Figure 1, from within the light gray circle the gray circles may be somewhat visible as things that behave as they do, but the black circles are not. In other words in the extraverse it is not relevant how or why the intraverse behaves as it does. Only the result or "design" counts. We as *conscious* observers may more or less 'see' both this intraverse and extraverse (such as hardware and software). But 'they' (the hardware and software 'themselves') cannot. They are different realms.

The point is: The extraverse is *made* to be causative – and alive – through providing it freedom. The extraverse *depends on* reductive freedom but is *not determined by* it – Polanyi uses the same words regarding mind and brain.[4]

Remark that *complexity* is not the key. Consciousness needs complexity because it is a consciousness *of something*. So it must be able to represent the complexity of something in itself. I present less complex, thermodynamical examples in section 4.

2.6 Examples of 'Invisibility'

- Software (and software engineers) use the instructions provided by a computer but 'they' have no idea how this hardware works;
- Information coded in DNA "supervenes" on biological cells living in an ecosystem. The timescale of the life and evolution of DNA (called "phylogenesis") is different from the life and evolving of a biological cell (called "ontogenesis"). They have no 'idea' of each other's lives;
- Your thoughts, perceptions and consciousness *live* in your brain without having any knowledge about neural networks nor brains.[12] *Lower level systems, i.e. intraverses, work for us, being caused top-down to do so*. We control our body extraversally through our thoughts without knowing how we do this because 'lower level' beings or systems, i.e. intraverses, do this for us. Thus is 'the nature' of top-down causation! It works this way because the 'higher level' or extraverse is made-up out of these 'lower levels' or intraverses which partly or wholly subdue *themselves*. In concrete examples it is, although often complex, completely clear how this works.

2.7 Relative Freedom

What makes this text somewhat cumbersome to write and read is that less absolute freedom will also create a somewhat independent system. Any non-linear causality will quickly cause some form of reductive freedom. Polanyi

speaks of this as that "the control exercised by the boundary conditions of a system can be reduced gradually to a vanishing point", which leads to a "continuous emergence of irreducible principles within the origin of life."[2, 4] Ellis speaks of this as "causal slack," which for him has to do with the non-continuity and the probabilistic nature of quantum mechanisms.[6]

2.8 'New' or 'Free' (")Matter(")

If the reductive freedom of an existence would be absolute then its 'inside,' intraverse, being or system would be 'absent' or 'unknowable' as seen from its extraverse, and *not causative* regarding anything in its extraverse. This will even be so when the intraverse is a kind of controllable engine (a la Carnot[15, 10'15"]) that can 'produce' or transform energy or movement. Then at least to its extraverse such an existence is a *particle* or *matter* – this said, an observer (standing outside of both this intraverse and extraverse) might see and understand both. This is not just a logical and necessary conclusion. This is *existential*. This is how our universe works. Examples of such 'matter,' though massless, are feelings and consciousness, but, so I claim, also 'ordinary' matter.[1]

Remark that this is what life, beings or systems generally do with 'input' and 'output'. *When* they become *predictable*, in the sense that a certain input leads to a certain output, then they are *not causative-from-within*. Then they *let* themselves be caused *by* their environment or extraverse. They *make* themselves non-causative – how could we not see this 100s of years ago?

2.9 Summary

An existence or flow-system is alive because it (i.e. its being or system) flows and because it persists (as design). 'Inside' it has a (flowing) intraverse (this is its existence as a being or subject). 'Outside' it is 'part' of another being or system, its extraverse (in which it is an existence as an object, design, particle or matter). Intraverse and extraverse result existentially from reductive freedom. Or better: intraverse, extraverse and reductive freedom result out of each other in a process of life and death. Reductive freedom is predictive of (the structure of) reality. *Find the freedom and you will find a being or system emerging.*

This is *absolutely not* a part-whole structure. Only when the parts and structure of a system 'disappear' (as 'seen' from within the extraverse) does it generate an *independent* system, i.e. a (new) being, having its own life. Your body and brain are not *visible* or *conscious* 'parts' of your consciousness, neither are various levels of unconsciousness living on top of each other in your 'mind' – see section 5. I will give some thermodynamical examples in section 4. Sorry to remain abstract for now.

3 Freedom Law

This is what I call the freedom law:

> When and only when reductive freedom arises, life can cause new natural systems or beings to come into existence, that is to emerge.

The freedom law predicts the *birth* of a new being or system. The law of life (i.e. the constructal law) predicts *how* and *if* this system will stay alive or die.

Remark that the constructal law in fact says: "If a system persists then it must..." etc. Or: "While a system lives it must..." etc. Thus while the freedom law may predict the birth of a new system, the constructal law may predict that this system dies.

Put in one sentence and without defining the term "reductive freedom" beforehand the *freedom law predicts* that

> a new, free (extra)-being or -system can come into *existence* when a being or system, thereby becoming its *intraverse*, forms and *determines possibilities*, i.e. *(reductive) freedom*, which, and the content or use of which, this intraversal system or being does not *completely* determine *itself*.

This "not determining" is the reductive freedom and this usually is or has been an active but persistent natural *process*.

In general, when there are no feedback loops within a newly emerged system then it will die. At the moment, for instance, we are killing our environment through pollution and overuse of energy-resources. Since we are conscious units making up this system, can we counter this? Or shall the system explode and end our lives too? Catastrophes are very natural:-/

3.1 Persistence, Life and Theory

Why is life and reductive freedom abundant? Because it is persistent! This is both logical and existential because we define life as the *persisting* and freely evolving being of an existence. Such an "existential logic" will be a feature of all laws applying to large quantities of things. Laws or logic connect different terms, semantic units, perceived qualities, phenomena, objects or meanings, and thus bring all these to life in theories. Next the *evolving* theories restrict or help to define the terms; think of "mass," "energy," or "life" as defined by Bejan. The constructal law, for example, relates "finite-size systems," "persistence," "life," "evolution," "freedom," "imposed flow" and "easiness of flow". There is tautology, but the semantics refer to reality, so it helps us to *understand* and *predict* reality. Neural networks are good at connecting semantics with reality. Logic lives on this, just as language and speech do.

3.2 Persistence and Death

So life is stable and persistent. But dead things may sometimes be even more stable and persistent. Biologically dead things dissolve, but physically dead things do not necessarily. For instance, new atoms come into existence in stars. They are rather 'dead' or 'bricked' at lower temperatures but with chemical freedom. If we see death as 'fixation' then other examples come to mind: DNA is quite 'fixed' ontogenetically. DNA evolves phylogenetically in a pool of living

beings, but not as a single DNA molecule. Memory in neural networks and brains is fixated in synapses. The design of a river is partly fixated in the sand that it flows in.

The aforementioned death need not mean 'forever dead.' If death means that what was alive *dissolves* then it is forever dead. If it means that it gets 'bricked' or *fixated* then it may come to life again if conditions change. Think of viruses, or of nuclear reactions that are only possible when heat and pressure are enormous. Reactions that *can* brick, ultimately *will* brick – conform Murphy's law[16] – which creates Ellis' "Evolving Block Universe".[1, 17]) But often what is seemingly dead just evolves at another pace.

3.3 Non-linearity and Feedback Loops

Non-linearity often means that without proper *feedback* something tends to implode or explode – exceptions are, for instance, sigmoid-like functions. Such must lead to death. Death means that evolution ends. Therefore we find feedback loops everywhere in living systems: biology,[18] our brain,[11, 12] electronics and weather-systems, *unless* a dead form or "design" is *very, very* stable or fixated.

Systems die. In the biological realm dead beings dissolve and disappear, thus only living beings remain. In the physical realm dead things may get 'bricked' or fixated, then it is these dead things that remain. In the mind of stubborn man one also finds lots of 'dead remains';-) Dissolving (and being removed from reality) after death is essential for the evolution of complex lifeforms – and, I would like to add, for improving (scientific) theories; and for one's mental and social health for which feeling ashamed is the psychic mechanism.

3.4 Reductionism versus the Constructal Law

Since the Constructal Law *assumes* the existence of freedom it presupposes *emergence* and it dismisses reductionism. Reductive freedom means being free from reducible or intraversal causality. It creates *'local'* or *extraversal* causality. This *causes* emergence of, for instance, consciousness and biological life. No constructal law nor life without reductive freedom. Reductive freedom (and emergence) mean that (local or) top-down causality exists since it is created by this freedom. But an intraverse (that is; lower level life) may break through in higher levels, for instance feelings influencing our consciousness, or people ending poverty or pollution.

3.5 Extraversal Explosion and Enclosure

An intraverse creates reductive freedom in the form of new 'material' or persistences. These substances then interact with each other and behave in a *determined* way. Thereby they (again) form a new, living and persistent system with *its own possibilities, rules and laws.* Together with other systems this

will again form an intraverse, which will form its own extraverse, et cetera, i.e. an 'explosion' of extraverses enclosing their intraverses.

'Counter-reductionistically' wholes determine parts. This is called "downward" or "top-down causation".[2] Wholes do this by forcing intraversal freedom or possibilities in a certain direction, thus *determining* an intraversal state. Whether this has other consequences in the intraverse is another matter. In our body, for instance, it often does have intraversal consequences. Think of stress and the placebo-effect because of thoughts we have. As Ellis puts it: "Top down causation [...] means having causal power over lower levels, channeling causal effectiveness at those levels".[19]

If there is reductive freedom then the life of a system or being can at least *start*. So people behaving habitually will create a social structure which has a life of its own. This living social structure will influence the 'states' of the people forming it. That may influence the habits of individuals, evolving everything, etc. Corning points out that when free entities differ, forms of *synergy* may arise.[20] Once people collectively act consciously, a social structure may brake down quickly.

4 Thermodynamics, Heat and Fluid Flow Examples

In most examples mentioned thus far the extraverses are complex. Then it is clear and undeniable how this complexity influences and controls its intraverses. In reality most extraverses are, or seem to be, much more simple. Understanding these will help to understand what the structure of extraverses living in intraverses entails and why it is not a part-whole structure.

4.1 Turbulence in Inviscid Jets

An example described by Bejan in 1981 is "the large scale structure and fluctuating behavior of inviscid jets".[21] The natural tendency of inviscid jets is to buckle over a precise wavelength which scales only with the jet diameter. This gives rise to a sinusoidal, river-like stream. Turbulence occurs when buckling and breaking up goes faster than viscous diffusion in the ambient. Thereby the wavelength scales with the transversal dimension of the jet only: $\lambda = D\pi/2$ for a round jet of diameter D. So we have a stream of trillions of molecules, and in the end their sinusoidal trajectory is determined mainly by the diameter of a cylinder around them. This is, even without understanding the exact mechanism, a clear example of *extraversal* determination of the behavior of more intraversal systems.

Each molecule gives possibilities, i.e. reductive freedom, of compression. All together they behave like an elastic column under axial compression, with its own possibilities, i.e. reductive freedom. What is going to live in this is the meandering of a stream. The diameter of the jet determines its frequency. The column vibrates as a whole. The column shakes individual molecules – and its constituents. This is top-down causation.

Thus this river-like streaming *lives* in a 'flowing' elastic column under axial compression. The elasticity of this column provides the freedom to this life. Even the elasticity of the constituting molecules is hardly of 'causal' importance since they have largely subdued themselves to the column as a whole. They only 'act on' external forces applied on them. (The column itself is not really alive but arises because of its molecules being artificially fixated in the jets exhaust pipe.)

4.2 Living Boundary Layers

Extraversal systems are not analytical, they are real. This is also how Bejan speaks of them. In 2020 Bejan describes how a boundary layer *comes to life* in between a blade and a moving fluid. He writes that such a boundary layer "happens in order to set the surrounding fluid in motion more effectively, more completely, and faster".[22, p. 2] Contrast this with Prandtl's classical theory where the boundary layer is 'only' postulated (against a semi-infinite background) and where its shape is calculated, unique and has not evolved.

Once you realize how a boundary layer (and more) comes to *live* in a system as a whole, you can model it as evolving into an ever better configuration, as Bejan did, and then you *understand* what is happening. To understand one must understand what extraverses are and do. To predict is not to understand.

4.3 Carbon-Dioxide Cycle & What an Extraverse is Not

An example in which we ourselves have come to be intraversal is the carbon-dioxide cycle in our biosphere. Oversimplifying this, plants turn CO_2 into organic material and oxygen, which lowers the green-house effect, which lowers the temperature on earth. This also lowers plant metabolism, which lowers CO_2 absorption. The other way round more CO_2 leads to a higher temperature and more CO_2 absorption. In this the earths oceans cause some 100 years of delay or phase-shift, leading to a slow oscillation of the earths temperature. This system is *persistent* and *evolving*, i.e. *alive*.

Remark that the system as a whole is *not* the extraverse. An extraverse should be something living *in* this whole. That whole consists of plants, trees, the atmosphere, the sun and so on, i.e. the biosphere. To give such a whole a name, call it an *exostructure*. Its parts then are its *endostructures*. This is a part-whole structure. That is not what this article is about.

In the intraverse some things are more or less reducible and explainable. But the system as a whole... The carbon-dioxide absorption of a single plant makes no difference to the earths temperature. Before we knew about the constructal law we would think the system to be either "stable" or "chaotic," possibly giving rise to "fractals." Now we know that, since the system exists for millions of years, it must be *alive*, in the sense that Bejan gives to life. It is not a 'chaotically ordered' "fractal" but a living "constructal" – funny how "constructal" and "animal" rhyme.

The carbon-dioxide cycle is clearly alive since we find freedom, non-linearities, feedback loops, persistence and evolution in the system. *That cycle* is what lives in our biosphere. Do not think of this carbon-dioxide cycle as a 'model' or a 'theory.' There is a really existing *being* of the type 'carbon-dioxide cycle' out there. In the example of the inviscid jet one could imagine a column under axial compression vibrating. In the case of the carbon-dioxide cycle this is not as easy, but it exists 'out there' nevertheless. Here the 'container' is not a jets exhaust but earth as a whole plus the heat of the sun. Although the carbon-dioxide cycle is not the biosphere, it will take the whole biosphere with itself, that is: with its own deterministic process, causing changes top-down, using the *possibilities* of plants, carbon-dioxide, radiation, and so on. As a being or system, *living* in this whole, it is very determining. It arises because of reductive freedom and it is resistant because of evolution and feedback loops. This is not a being or system that only exists in analysis. It is an irreducible, really existing existence. This is also how Bejan speaks of such systems, as in [22, p. 2], quoted here in section 4.2. In fact this often is how we all speak about it, but without understanding it, I think.

The whole is itself not the extraversal system, yet we find the extraversal system within this whole. From our deterministic worldview we keep mixing this up – me too, unfortunately; it really is a completely different way of thinking than we are used to. But since the extraverse is living in the intraverse, which, because of its own life, subdues itself to the extraverse, this intraverse changes along with the extraverse. That is what we "see" to happen, and what a reductionist erroneously thinks to be causal.

Is the carbon-dioxide cycle a system that we 'communicate' with? Or is it a system that lives 'on top of us' and that 'determines' us? We 'feed' it by burning fuel and killing plants, or the opposite, but for now there seems to be too little feedback that might change *our* behavior – remark that feedback 'using' humans usually is *moral* feedback requiring accountability and recognizing the facts, i.e. that the mental copy or 'truth' in our minds conforms to reality.[12] Since the carbon-dioxide cycle is *alive* it *resists* change and in doing so our climate *evolves*. When CO_2 becomes too high, forests will burn and catastrophe sets in. By killing *us* the system makes room for itself. If things would really go beyond the degrees of freedom of the system then it would die and dissolve, but in this very resistant case probably evolve anew. So we, humans, are part of the system in which the carbon-dioxide cycle lives. It will kill us too survive.

4.4 Ignored Complexity

Real systems, especially engineered systems, are usually much more complex than one thinks of. It is easy to forget the complexity of interconnected or communicating systems. Engineered systems are made for people, so here there is always a social component. For instance, nuclear power may seem clean, although somewhat risky. But have you thought about the trade in nuclear knowledge and materials that it causes? This may again be a living system

and this will take care of *itself* as long as it is alive. For the good to find *us* we must not ignore anything, I think. Ethic accountability is mandatory for survival.

4.5 Discussion – Entropy

In the year 2000, in his first full-length book on the constructal law, Bejan wrote: "To account for coupled thermomechanical behavior Rudolf Clausius had to formulate a second principle, the second law, in addition to the conservation of energy. With this new principle came the concept of entropy, which was completely foreign to science. Today the new principle is the construction of geometric form, and the new concept is objective, or purpose".[23, p. xix] The book concludes saying that "modern physics embarked on a course tailored to the principle of infinitesimal local effects. Constructal theory is a jolt another way, a means to rationalize macroscopic features, objective, and behavior."[23, p. 314] I read "macroscopic" as "extraversal" (and not as "exostructural").

I think that "entropy" or (more clear) "negentropy" is a value that expresses the amount of *extraversal* life, fixated death, and design of a system.

With a temperature above zero Kelvin, there will be *intraversal* life or "energy," being the energy or movement active in each particle. Since infinitesimal things do not exist, i.e. there is a minimum (Planck) size, and since energy and mass are conserved, intraversal life will lead to a minimum negentropy, thus a minimum life, because a completely 'dead' equilibrium can never be achieved. The universe as we see it may well be such a minimal order. In its current form it will need its enormous size. Without it there could not have been heavy stars and heavy elements.

This article emphasizes the reactivity of intraverses, not them having energy, because that makes my argument more clear. But living systems always consume, transform or produce energy. Originally all energy came out of the (quantum mechanical) intraverse. In the end this produced things like stars and nuclear heat. Entropy from these can be used by other systems to lower their entropy. This way Clausius' law holds – until fundamental quantum non-continuity and randomness comes into play.

5 Constructal Causation of Consciousness

Your thoughts, perception and consciousness *live* in your brain. Language *lives* in human communities. Truths *live* in spoken and written language.[12] Language and truth have aspects of consciousness since they can represent things in themselves. But language and truths live in us like a virus with limited freedom. Sometimes 'truths' or 'beliefs' dominate, sometimes you do.

Next I shall show and 'build' (part of) the minimal, prototypical human hardware that may cause consciousness. My aim is to convince you in every possible way of the true existence of extraverses.

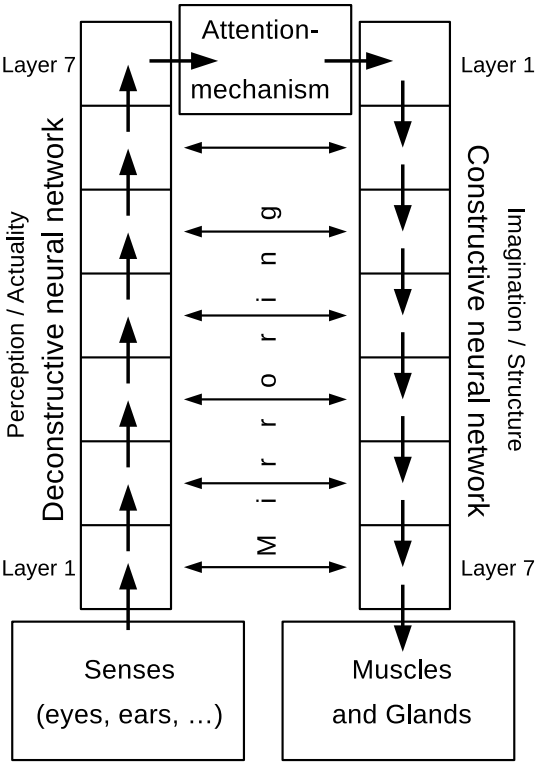

Figure 2 Mirroring neural network

5.1 Mind and Brain – Software and Hardware

A state of mind is also a state in its neural machinery. The former consists of thoughts and perceptions, the latter consists, to put it simply, of electrical activation patterns of neurons (and their memory, but I will mostly ignore that for simplification). Brain-states and mind each involve completely different realms. One is described using states existing in *intraversal* matter, being neural activation patterns. The other is described using *extraversal* 'matter,' being (lower or higher level) thoughts and perceptions. We can understand both our mind and the activity of our brains as seen in a brain-scanner, and we know from experience that both are real and that both exist. With the freedom law and the law of life, we can see how both are part of the same, really existing structure of being in which neural *content* is (deterministically) *causative because of* reductive freedom created in the neural network.

5.2 Creating neural Freedom – the Hardware

To fill in the details, let us build a neural network functionally resembling our brain to show how reductive freedom arises in it.[11, 12] Imagine two neural networks (feed-forward without having error-back-propagation) of about seven layers deep. In humans the equivalent of a neural layer is a brain region. Take the two networks and 'lay' them next to each other such that the output of one network lies 'against' the input of the other. So layer 7 lies against layer 1, layer 6 against layer 2, and so on; see Figure 2.

Attach the input of one network to our senses and call this our *deconstructive* or *perceptual network*. To each layer in this deconstructive network add inhibitory, 'winner-take-much' neurons, so that the layers learn to discover and classify features in what is perceived, with lower layers allowing much more winners than higher layers. In the highest layer only five may win, which we experience as *attention* and which we may therefore call an "attention mechanism."

Attach the input of the other network to this attention mechanism. This network I call the *constructive or reconstructive network*, or sometimes also, using terms from the philosopher Tadeusz Kotarbiñski, the *reproductive or productive network*.[24]

Part of the neurons in these two networks are connected in a special, *mirroring* way. This means that when such a neuron in one of the networks is deactivated it also decreases the *sensitivity* of the mirroring neuron in the other network. In a sense these mirroring neurons together form one neuron but each is in a different network – sort of like an 'entanglement of two particles' (in ART neural networks that work similar to my model they are indeed one[25]). The end result is that the two networks tend to *mirror* each other, but with neural activation running in opposite directions with respect to each other. (Remark that this mirroring between the constructive and the deconstructive network is also a biologically possible way of error-feedback-propagation.)

5.3 Reconstruction Mirrors Deconstruction – the Software

The idea is that through one network you can perceive, abstract and decompose things into pieces or wholes – *deconstruction* – while through the other network you can *construct*, produce, *reconstruct*, reproduce or *imagine* things. Again and again from the attention mechanism a handful of neurons is activated in the *(re)constructive* network, causing neural activation to flow back toward the senses. In the absence of perception we experience this as *mental representation* or *imagination*. This also has temporal aspects, but that is too complex for this article to delve into.

The inhibitory neurons in fact form attention mechanisms in *every* layer, but in lower layers much more can be attended to than in higher layers. There are hundreds to hundreds of thousands points of attention in lower layers.

Imagine this: You are looking at a painting. That is a complex pattern entering your neural network through your eyes. Don't think this enters as an 'image,' it is just billions of electric pulses. Your young brain at first does not even 'know' that these are coming from your eyes. Inhibitory neurons cause abstraction. In your eyes contrast is amplified. In the first neural layer lines, colors and movement are detected. Higher up increasingly complex shapes are detected. Then there are layers that are more concerned with meaningfulness or spatial organization. Eventually the attention mechanism allows only five winners. From the attention mechanism(s) neural activation flows back through the (re)constructive network in the direction of the senses and our muscles. Because the deconstructive and constructive networks tend to mirror each other, this reflux activation will tend to be a *reconstruction* of the observed. As such there is a mutual "*reinforcement*" of deconstruction and reconstruction – Grossberg and Carpenter call this "resonance".[11, 12, 25] This self-reinforcement is a relatively stable situation in which neurons either excite each other for a relatively long time (about 25ms) or, conversely, they do not. It will become even more *persistent* because of it being *memorized* as *knowledge*. Here is where thoughts and knowing *emerge* as *life*!

Knowledge in neural networks is *distributed*. A consequence of this is that different mental 'things' are not conscious at the same time. They are persistent as *knowledge*, not as *knowing*. But we can know and be conscious of them again and again. Our daydreaming goes on and on.

In each neural layer we have the process of deconstruction and (re)construction. The reinforcement through mirroring gives *persistence* while *evolution* is still possible. As such there arises *reductive freedom* in every neural layer, which is 'given' to the layer just above it – and in this remarkable case also to the layer just below it. Each layer has a different content. The content of one layer is 'build on top of' or "supervenes on" the content of another layer, e.g. visual forms are built up out of lines. Remark that even these lines are alive. They shall try to *act* if they *think* to fit an extraversal form, or if they *think* to fit an intraversal collection of contrasts. They are also extraversally *acted on* to fit in. They succeed when they win attention over others in their neural layer – or their level of consciousness.

Note that "*con*tent" and also "*con*sciousness" are somewhat confusing words in this context because they suggests to be something that is *in*side something else, such as text in an article, while in this text we see content as *extra*versal – I finally swapped the meaning of the terms "intraverse" and "extraverse" as in this text to comply with emergentist theories.

5.4 Consciousness and Intraversal Patterns

The reader may imagine that, if you would want to try to reduce what is happening in a system ever lower into intraverses of intraverses then you would see *ever more complex patterns* of (states of) *life* or processes. Systems are built 'on' 'simpler' systems and they are (at least partly) controlled *top-down* from out of *their* extraverses. Since there is reductive freedom in between every

system, none of these intraversal systems is *fully* causational. To the contrary, the extraverses are *made to be* causational and hold on to this while being alive or while partly being 'bricked' in a 'lively' way. Extraverses are only less causational if there is (non-free) intraversal input into them such as emotions, instincts, pain or simply *perception* influencing thought and perception.

A reductionist might complain that each term or input into an extraverse can be formulated in intraversal terms. Yes, of course. Freedom arises in this intraverse – ultimately in Figure 1 the connections are between the black circles. Yet *prediction* from out of the intraverse, i.e. *reduction*, *is impossible because of reductive freedom*. That is the essence.

Our consciousness, I claim, is a hierarchy of systems – qua hardware of about seven layers – of which we do not fully know its intraverses. It is a multilayered, temporal structure of extraverses created out of each other, or in other words of intraverses created inside each other.[12] The attention mechanism you experience as the "I" 'wandering' in your consciousness – except when attention dissolves in a near-death experience and such like, which I thus consider to be a prove of my theory. Just *below* the top we have a preconsciousness of which we understand its existence as intuition or as part of our feelings. The lower layers we only get to know somewhat through psychological tricks and tests, and through brain injuries. Examples of intraversal life are: lines in images, phonemes, basic forms, concepts, basic emotions from your more primitive brain structures, complex feelings, the largely 'automatic' car-driver or baseball player inside you, etc. If parts of your intraversal network start to rule, for instance induced by fear or too much neural noise, then you will be in a psychosis. Reductive freedom of the higher layers, i.e. top-down causality, is mandatory for sanity.

Remark that both our consciousness and reality are structures of intraverses in intraverses. Our consciousness is well adapted to the structure of reality. Language is less so. It is very difficult to arrive at a correct, not estranging theory.

5.5 Metaverses and Truth

To make this article recursive:-), let us take language and truth as an example. Language runs in us as an exemplar or specimen of a species – just, as it were, like a virus that uses us. Language speaks (or should speak) *us*, not itself. Language makes the existence or being possible of truth and representation. Truth arises with the possibility of lie and nonsense. It is speaking without lying and without uttering nonsense. Each truth is a set of laws, facts and *possibilities*. Truths take on a life of their own by being copied, imitated and supplemented. Truths live in us as exemplars of a species, with great variety and with enormous possibilities of mixing and evolution through exchange and testing of truths – in as far as we are not totalitarian.[12] Special of truths, and also of consciousness, is that these are beings or systems mirroring other beings or systems. Thus they are *meta*verses. In a metaverse *copies* – or 'translations'– of other beings *live*.

Language lives in us – it even speaks us. I think that in language one can find implicit theories about the world. This means that one can study language and its history to track our understanding of the world. I hope to add the terms "reductive freedom", "intraverse" and "extraverse" to it.

The other way around, writing a book is how I, with help of the Dutch language living inside me, discovered all that is written here.[12]

6 This Theory...

I think my theory shakes up too many things to be understood and accepted instantly. But you, dear reader, who already know and accept the constructal law, are among the few people on this planet who can understand it. With that you understand the structure of reality as it necessarily (and predictively) is.

Statements and Declarations

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