Invited Article

Emergence and Organization
Towards a Taxonomy of Organizing Relations

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Abstract
There are effectively two classes of explanations for how we come to be conscious, particularly in the sense of having a “mental world” or apprehending and comprehending phenomenal experience of both the material world in which we are present, and the worlds of our imagination. These, of course, are the physicalistic explanations in which consciousness somehow is a product of the brain’s activity in the physical world, and the mentalistic (usually dualist) explanations in which some non-physical “stuff” carries our mental worlds and phenomenal experiences. Ultimately, even if the mental stuff hypothesis is proven to be the case, we will still have to produce an explanation for how there can be a causally efficacious connection between that mental stuff and the physical world.

Key Words: mental world, physical world, consciousness

I. INTRODUCTION
The world in which we operate is, by definition, physical and the objects and processes of that world are necessarily physical. Nevertheless that physical world is mysterious, and worse it is hidden from us, rendered invisible by the means through which we sense it, since all our senses are biologically within us and what we know is what our senses provide our brains. Our experience of the world and our understanding of it leave us with quantum physics which, while technologically highly effective, does not bring us into any closer contact with the world than that which we gain through the mediation of our senses. All that we have is our knowing, our explanation of things, driven by our experience of the differences in the world, guided by our own cultures, languages and beliefs.

So, here, I want to examine the use of emergence as the explanation for how consciousness can occur in a physical system. Physics itself is understood within the terms of a reductionist paradigm in which the behaviour of some “object” is sought in the properties of the microphysical components of that object. Higher-order objects are then described by some process of building up an object from a collection of parts and their interactions and, when this gets to be too complicated to do, or apparently impossible, a mechanism of emergence is invoked as though that
was sufficient explanation. This use of the term substitutes what is really shorthand for detailed explanation, and thus the difficulties of understanding the presence of the whole, organised systems and many aspects of the nature of biological organisms arise.

I am going to consider ontological emergence, *i.e.*, the emergence of objects and systems from the *matter* of their constituents. Now, given that this paper looks at the use of emergence as an explanatory possibility for consciousness, some readers will regard this as an act of cutting off one’s nose to spite the face, in that for many from Descartes to Chalmers, consciousness, phenomenal experience and qualia do not consist in material stuff but consist (in some unknown way) in mental, non-physical, stuff. Despite their convictions, this is not a proven situation and it may well be that consciousness is an emergent property of a *suitably organised, entirely physical* system. One of the reasons emergence, as an explanatory principle, is adopted is that it *seems* that there are numerous examples of physical configurations of systems which do not support the prediction of behaviours which these systems, when suitably constituted, may demonstrate. Effectively any ascent up the levels of, particularly, the biological orders produces new or emergent objects or systems as we go up those levels. The behaviours, or properties, of a cell are not predicted by the isolated behaviours of any of the macromolecular components of the cell, in fact many of the behaviours of those macromolecules don’t even come into operation until they are integrated into a cell [the term "downward causation" may be applied here]. This also applies for multi-cellular animals and for the “emergence” of consciousness in the highest-level animals. The use of emergence in explanation has particular relevance in physicalistic theories of consciousness, since it is often considered that consciousness is an emergent property of the organisation of the brain (Newman, 1997; Edelman, 1989; Crick, 1994; Churchland, 1995).

Both emergence and its converse, reduction, have received a considerable amount of attention recently (Searle, 1992; van Gulick, 2001; Silberstein, 2001) and I shall initially review some of that work so that we can be talking in more or less the same language. Following this I want to suggest how a whole might be greater than the sum of its isolated parts by establishing how the emergence of a whole develops through the presence and processes of the relational properties [for which I shall use the term "organizing relations"] that are available for some "part" to interact with other "parts" in its locality.

II

Reduction and emergence, to most authors, work in contradistinction to each other (van Gulick, 2001) Reduction is a matter of analyzing a system down to its minimal parts whereas emergence is a means of explanation by which the parts integrate or become coherent in some way so as to synthesise something more than just the sum of the parts, namely the whole. At the levels of the world for which we generally apply classical dynamics reductionist modes of explanation work well and usually, we would not even think of invoking some version of the concept of emergence in our explanations. It is only when attempting to explain the coherence, integrity and wholeness of things for which the properties that we know of their constituents appear to be inadequate, that we invoke emergence as a gap filler (*e.g.*, the emergence of life from non-living chemical activity - once known as "vitalism" - and the emergence of consciousness within living systems.)
Reductionism

Reduction is a means for developing explanations of some sort of object or process based on the simplest possible microphysical constructions. Many authors (Searle, 1992; van Gulick, 2001) describe reductionism as a “nothing but” relation between things: Some thing A is made up of nothing other than certain other things B. Lockwood asks “whether there is anything that in principle is going to be left out of any description, however comprehensive in its own terms, which is couched purely in the language of physics”? (Lockwood, 1989). He thinks of reduction as being the explanation of, say, a physiological event in terms strictly of physics, i.e., that the physiological states that one might feel oneself to be in are a function of the materials of one’s physiology. And he describes the material as “those things … that occupy or take place in space, and whose existence is ultimately constituted by the properties and relations, actions and interaction of particles and fields, or whatever basic entities physics treats of.” (Lockwood, 1989). Although some, eg, Stapp (1993), seem to consider that the object for which a reductive explanation is to be developed is simply the sum or aggregate of its parts, we should properly suppose that they consider that the parts possess their properties intrinsically rather than that they are a result of the interactions of those parts.

Reductionism, then, is about analyzing an object into its constituents and describing the relations that integrate those constituents into the object. Thus van Gulick (2001) asks what types of things “are reductively linked” and what kinds of links are involved? Because I am dealing with ontological reduction here I will focus on the links or relations that persist among objects, properties, events and processes within the distinct paradigms within which they are understood.

Van Gulick sets the scene for my discussion by saying, when discussing types of ontological links, that something being

“composed entirely of physical parts is not the same as saying that all its parts are entirely physical, to assert the former is to say only that all its parts have physical properties, but the second asserts that those parts have only physical properties.” (van Gulick, 2001, p.7, his emphasis).

It is this stronger second position that I wish to adopt. I will examine how reduction might fare when the nature of the relations of linkage between objects is explored in some depth. I argue that what gets called emergence will occur in the proper operation of these relations, and I will develop a taxonomy of the kinds of relations that do so operate.

Emergence

So what is emergence? By what processes does it arise and what are its characteristics? The phrase “the whole is greater than the sum of its parts” is the common way of saying that something is emergent from its constituent parts, but seems to be based on an assumption that the parts and their properties are identical and thus depends on the question of just what the properties of an object are. Given that generally the properties of an object depend on the relations it has with other objects, these properties remain in potential until brought into some sort of direct causal “contact” with some other object. It then becomes trivially self-evident that a whole is greater than the sum of its parts when the properties of its parts are not considered to be variable relations that depend on the environment of the whole, its components and the conditions of their causal “contact”. That the properties of an object change depending on such other objects as they are in causal “contact” with holds for the very simplest of chemical combination right up to the most
complex and intractable of human relations. Explanation of these processes requires the nature of the relational links to be demonstrated.

Many authors suppose two kinds of emergence, a weak or modest kind and a strong or radical kind.

**Weak or modest emergence** is largely considered:
- to be “the doctrine of real unities being more than a mere collective disjunction of component elements.” (Whitehead, 1929, p.349),
- to depend “on interactions that are more than the sum of local interactions” (Holland, 1998, p.189)

and operates in cases
- in which “the whole has features that are different in kind from those of its parts” (van Gulick, 2001, p.17)
- or where the features of the object cannot be simply explained by the environmental relations of the components but have to be explained via the causal relations of interactions among the components (Searle, 1992). For example, for Searle consciousness cannot be accounted for by the simple mass or “sheer physical structure of the neurons without some additional account of the causal relations between them” (Searle, 1992, p.111).
- or where an object having emergent properties is physically determined by the properties of some lower level constituent, yet would not exist as such without those emergent properties. (Collier and Muller, 1998).

**Radical emergence** arises
- as a more adventurous form of emergence in objects whose integrity cannot be explained by the causal interactions of the features of the components (Searle, 1992).
- as that in which the “emergent” properties of the whole are, or appear to be, metaphysically incompatible with the properties and relations of its parts, perhaps involving the appearance of a totally new (e.g. mental) stuff.
- where “The whole has features that are both
  1. different in kind from those had by its parts, and
  2. of a kind whose nature and existence is not necessitated by the features of its parts, their mode of combination and the law-like regularities governing the features of its parts” (van Gulick, 2001, p.17).
- where the object or property is deducible from the properties of its constituents (Collier and Muller, 1998).

As van Gulick points out there is not a lot of acceptance of radical emergence since it involves giving up the atomistic view of causal determination held by most mainstream physicalists and the adoption of a concept of ‘downward causation’. The kind of properties such as the apparent mental properties of qualia or thoughts that we usually consider consciousness as having, would have to be radically emergent if one were to retain a dualist theory of mind and still desire to have a physical brain in which mind operates. For some it may also be the property that living as opposed to non-living entities possess. Searle (1992) argues that consciousness is not radically emergent, since consciousness could then bring about effects that could not be explained by (nor mediated by) the neuronal components in which it is realized. In the argument canvassed here, what radical emergence is used to “explain”, viz. consciousness, is accounted for in the function of
the organizing relations discussed in section V. Downward causation will be seen to be a reading of changes in the apparent properties of constituents wrought through the process of their integration. The changes in their properties cannot arise before the integration, and can only be seen because of that process. It is rather like the meaning of a word changing according to its context.

III Characteristics of emergent systems
Emergence is probably best represented as a shift or jump in hierarchical levels of organisation of the parts of some system such that they become integrated and might be characterised as being something with a new name. We might think of this as akin to the idea of concept formation or perhaps a collection of trees being seen as a forest. The problem of emergence to a large extent engages questions of whether it is meaningful to talk about hierarchical levels of organisation in systems, how one might describe the boundaries between levels and how a collection of constituents can actually cross or jump levels. These issues concern every level of science from the jump between quarks, gluons and electrons to nucleons, atoms and ions in micro-physics to the difference between collections of organic molecules and cells or the organisation of individual humans into societies and cultures. Emergence then becomes the question of organisation and I will proffer a taxonomy of "organising relations" by which it can be conferred on a collection of parts giving them integrity, coherence and the status of a whole.

Emergent systems possess certain characteristics that can be described as being those of a dynamical process showing

a: novelty (Bickhard, 2000).

“The intuition of emergence is that of novel causal powers coming into being at specific levels of ontology” (Bickhard, 2000) An instance of emergence would be either the first time something appeared in the universe or more interestingly the emergence of something new with every instance of a particular organisation of lower level constituents. I.e, the appearance of a living thing with every complete ensemble of the molecules necessary for the replication of DNA (Bickhard, 2000). This can also be thought of as being the “acquisition of new capabilities” by a coherent system (Collier and Muller, 1998).

b: unpredictability
For Broad the unpredictability of the properties of something was at the very basis of calling it emergent (Broad, 1925). This view has been criticised on the basis that the determination of emergence is then contingent on our knowledge of the systems under consideration at the time (Collier and Muller, 1998), rendering it a characteristic of representational rather than ontological emergence. Collier and Muller (1998) also point to special cases of unpredictability such as deterministic chaos in dynamical systems that can occur in sub-regions of a systems’ phase space, but that this cannot provide a basis for distinguishing between emergent and non-emergent properties in the time evolution of the system.

c: cohesion or coherence, integrity
Refers to objects that are “held together by causal interactions that constitute their organic unity… Cohesion represents those factors that causally bind the components of something through space and time, so it acts coherently and resists internal and external fluctuations.” (Collier and Muller, 1998). I also use the term integrity in this sense. Collier and Muller claim that cohesion is analogous to non-linearity and suggests that some kinds of non-linearity, such
as feedback loops, are “obviously cohesive” (Collier and Muller, 1998). We will explore feedback as a relation in section V (Taxonomy of Organizing Relations). However, they also claim that cohesion is irreducible arguing that cohesion confers properties upon something “that are not merely effects of the properties of their components.” This is effectively their definition of emergence. But, as I argue below, suitable consideration of the integrations of properties within levels of the organisational hierarchy of things implies that these cohesive properties are (in principle) precisely explainable in a series of reductionist procedures that acknowledge the organisational hierarchy of things (otherwise emergence cannot have explanatory force).

d: self-maintenance
Also described as ultrastability by (Ashby, 1952) it reflects an object’s contingent stability with respect to variations in the environment (Holland, 1998). Collier and Muller (1998) consider self-maintenance to be part of the cohesive nature of an emergent system. For Bickhard (1997), in an open system, the supply of “fuels” from the environment must be maintained but, more importantly, the conditions for use of those supplies must be maintained by the open system’s own behaviour. A successfully self-maintaining system will remain stable with respect to the world. If the self-maintenance is disrupted by some (catastrophic) change in the source of “fuels” for this operation then the system will cease to be maintained, losing its coherence and will disintegrate. Metabolic self-regulation in organisms will also be a form of self-maintenance.

e: causal asymmetry
Bickhard (2000) argues that the appearance of “novel causal properties” in a system is an essential criterion for emergence. These novel causal properties are a function of the integrity of non-linear systems where the behaviour of the system at its system level contributes to its self-maintenance and its integrity.

i) downward causation (Bickhard, 2000).
The causal effects wrought upon its constituent sub-systems by an emergent system occur through a "downward causation" and one would expect that it would be a necessary criterion for an emergence. It is a function of the hierarchical levels of a system. An example would be that the opening up of pores in a cell membrane to admit necessary food molecules is brought about by the overall self-maintenance needs of the cell, though the details of the process are micro-physical being the internal metabolic processes of the chemistry of cell. The problem with downward causation is that it appears to violate the causal closure of the microphysical world. But must we reduce all downward causations to micro-behaviours of the constituents of the system? The real interest in emergence in this sense is that it reveals relations amongst constituents of a cohesive system that we couldn’t have known about if the emergence had not obtained.

ii) non-linearity (Bickhard, 2000)
All biological systems are non-linear, maintaining themselves in far-from-equilibrium conditions. Linear systems cannot be emergent on the basis of simply additive relations, but it turns out to be surprisingly difficult to find purely linear system. Even a pile of sand has non-linear properties in the criticality of its collapse as more sand is added. This criticality is an hysteresis in which the pathway up from constituent level to whole level is different from the pathway down from whole to constituents.
So the question of emergence really becomes how can a system develop these characteristics? That is, by what mechanisms do these properties arise so as to make an ensemble of parts into an emergent whole? All the behaviour of the physical world involves the evolution, over time, of the organisation of things. At the Big Bang, the start of everything from some sort of singularity, nothing that we know today could have existed given the temperatures and pressures that would have been present at that moment. From the quark/gluon soup to the emergence of living conscious beings is a long process of ordering and organising forces and parts. Objects come into being over time and thus there must be some process by which the minimal parts of microphysics become integrated into the larger more organised parts that we know today. The potential properties of some aspect of the physical world, on being enabled through some sort of proximity or collision, produce combinations which amount to the emergence of a new object. Within this long process large macro-molecular cellular systems could not have come from the quark/gluon soup directly. There must have been some sort of intervening steps. At the very least quarks/gluons\leftrightarrow protons/neutrons/electrons\leftrightarrow atoms\leftrightarrow molecules\leftrightarrow macro-molecules\leftrightarrow cells and so on up. These intervening steps amount to degrees of organisation, levels in a hierarchy of order. Each level cannot come into being until the previous level is fully established and we see this epigenetic sequencing as the history of the universe. Since the Big Bang nothing that exists can have been made from something other than what previously existed. Each new level of object in the universe is emergent upon its constituents. In explanation this emergence is the reverse of reduction and any emergent object must in principle be reductively explainable.

Thus the universe is in process and through the organisation of its constituents, a function of its organizing relations, the more complex objects of the universe are enabled to emerge. Although a full description of the process involved in any particular emergence may be intractably difficult such a description is, in principle, possible. In the deconstruction of vitalism as the principle that brought inanimate matter to life in biology it was recognised that the organising relations that had been attributed to some vitalistic (and therefore radically non-reducible) principle were in fact the proper study of biology (Needham, 1936). It is with a similar intention that I propose the exploration of the organising relations of self-reflective (or cybernetic) systems as the proper study of a science of consciousness. Ontological emergence thus becomes the question of organisation and we will look at a taxonomy of relations by which organisation can be conferred on a collection of parts to give it integrity, coherence and the status of a whole.

IV

So I am arguing then, that emergence might be best thought of as the development of organisation among the constituents of a system. As my primary purpose is to argue that consciousness could have evolved from physical processes of the world I have to show that the global system properties of the emergent class "mental" are dependent on the kinds of relations that can actually be operating in the physical world. To start this I want to extend the concept of relations and introduce the idea of orders of relations. What we need is a collection of “laws of organisation” (von Bertalanffy, 1968, p153).

Organising relations
Since my point about explanations of emergent objects is that they come through the description of the kinds of relations that link objects within the level of an integration and between the hierarchical levels of order, I should provide some sort of definition of order. Von Foerster suggests that order allows us "to account for apparent relationships between elements of a set which would impose some constraints as to the possible arrangements of the elements of this system. As the organization of the system grows, more and more of these relations should become apparent." (von Foerster, 1960, p.37). He then proceeds to derive a relation between the order and the entropy in a system such that for a system to be ordered it must carry less entropy than the maximum possible entropy of a set of the same elements not in any way so organized, i.e., a system wherein the elements are not in any relations (other than random spatial relations) with each other. So to produce order in a system it must possess relations among its elements which have the effect of reducing the indistinguishability of states of the system, thus organising it.

Now, if the system so organized becomes capable of some level of stability such that it develops constrained regions having boundaries and that for perturbations to its elements or its boundaries to be damaging they must be greater than a certain threshold, then that system can be said to be integrated (Ashby, 1952). This integrity in a system gives it its emergent condition as a new order of object (or ontology) and we can then go on to describe various levels of order in which a set of integrated elements at one level become the parts which, in utilizing further kinds of organising relations, constitute a new, higher level order. These organising relations are complex networks of interactions among the physico-chemical and biochemical entities of biology (Waddington, 1977, p20) and/or among the neuroanatomical structures of the brain and/or among the individuals of a society.

We might think of these organising relations as being horizontal (or intra-level) and vertical (or inter-level) relations. Horizontal relations are the interactions within the cell. Vertical relations include combinations of these horizontal relations which bring about the completeness of the cell as a cell. Here the failure of any one horizontal relation will not necessarily bring about the collapse of the cell since diverse reaction pathways may accommodate, for example, the lack of a particular feedstock molecule. However there would be a point at which the collapse of enough of the relations would bring about the death of the cell. Vertical relations beyond the step up in order from, say, macro-molecules to cell, would include such behaviours as the cell emits to interact with other cells (at the cellular level) to produce a combination of cells which become, say, an animalcule. The ingestion and production of molecules as fuel and as signals, respectively, (from the sub-cell level) by the cell will contribute to its incorporation into the super-cellular level that would be a multi-celled creature. Here a diversity of cell types also engage in horizontal relations that bring about the “emergence” of the creature on an organisational level.

Though the physical carriers of relations at higher levels of the hierarchy of emergence become less obvious, or at least more complex, the situation can be shown to continue likewise, going up the levels of organisation to organisms and on to societies and cultures, etc. For example the types of bonding made possible by valence electrons allows the coherence of macromolecules such as amino-acids and sugars and on up to proteins, nucleotides and ultimately DNA. The exchange of small molecules by enzymes in protein synthesis creates further macromolecules and in a cell the multiple classes of molecular exchange mediate the overall coherence of the cell as an emergent object, a single whole entity in itself.

Nature of relations.
So we must look at the nature of what relations actually are. Whitehead defined relations as such: “What are ordinarily called “relations” are abstractions from contrasts. A relation can be found in many contrasts; and when it is so found, it is said to relate the things contrasted.” (Whitehead, 1929, p.3499 where a contrast is a difference between two perceptions (occasions of experience) such as the contrast between red and blue. Whether or not one considers experience as an information processing activity it nevertheless has considerable informational content and it is the relations between things that allow us to distinguish information about them. Thus the ontology of information is crucial to the understanding of relations.

What we experience from the world are what our sensory systems are actually attuned to: the changes of states of physical characteristics and properties of the world, eg, reflected light of a particular limited spectrum of wavelengths, pressure waves in the atmosphere (again of a limited bandwidth), pressures and temperatures on our skins, etc. These changes in quantity of the physical world's impacts upon us become available through differences (Whitehead's contrasts) in the experience from one moment or state to the next in the process of sensing and being in the world - it is these differences (the changes in phase-space of the properties operating in the interaction of the energetic impacts of the external world on our perceptual apparatus) that we sense as information about the world. So in this manner what we know or experience of the world is Shannon information being, at the sensory surface, syntactic and empty of meaning: it resolves distinctions thus reducing uncertainty; this particular event was either this or not-this and with this single distinction order is increased, the world becoming one bit more organized (Shannon and Weaver, 1949).

Bateson's (1973) concept of information as being the difference that makes a difference is derived very largely from Shannon's concept of information, but with an overlay that was probably brought in from Weiner's (1948) feedback function; that is that there is a system to which the information presented to the sensory surface is able to make a difference, thus bringing in the meaningful (at least in a primitive way). As such information can be seen as a function of difference relations among particulars of the world. Being in the world these difference relations are physically embodied and whether or not "information" is present in the external world (outside one's skin) or only internally in knowing "minds", that information must be physically embodied.

If information is a function of a general class of difference relations and observation is a process of generating information and explanation is a function of a calculus of difference relations, the knowable world is then a function not of any particulars as such but of the relations by which these particulars have their properties. It is the relations that provide the information observable as properties and as such might be seen as being more fundamental than the particulars that are exposed via these relations. In fact the particulars couldn't exist if the relations did not operate. Therefore the knowable world, as we know it, is a function of the physical relations between its particulars.

So what these processes of combination and interaction - that produce molecules from atoms, cells from collections of molecules, complex creatures from collections of cells - are needs to be explicated. As I have alluded above they are the organizing relations that, in concrete terms, say chemistry, appear as the valence bonding properties of an atom of some element. They operate as electron release behaviour of atoms of some element X in interaction with electron take-up behaviour of another element Y. Experimental investigation of the molecule XY led to the discovery of chemical bonding and its explanation. It is the relations between X and Y that lead to
the elucidation of the properties of X and of Y (Kossel, 1916). Knowledge of the relations is represented as the properties of X and Y. But X’s and Y’s by themselves will not show behaviour that could lead to the discovery of those properties, this can only occur through the investigation of the relations between X and Y - obviously a mere collection of atoms could not produce a molecule if there were no interactions.

V

Taxonomy of Organizing Relations

The bases of such properties of emergence as cohesion are in the organisational relations that I will explore in this section. They might be described as causal and are what I and others (Bell, 1999), call feedforward relations of the type B depends on A, but B offers no behaviour that could influence A, and cyclical relations in which the behaviour of some object influences its own further behaviour or mutualistic relations in which several objects influence the behaviour of each other. I offer here a modest attempt at a taxonomy of the kinds of relations that could organize the parts of some ensemble into a coherent whole. The first and most prosaic are simple environmental relations.

Environmental relations

The basic relations of arrangement or composition such as shape, weight, velocity (Searle, 1992, p111). They are not causal relations but relations of topography, usually randomly produced, the accidents of an object. They will not be in any important way relations of organisation and one suspects have very little to contribute to the emergence of an organised object other than the opportunities they afford for other more interactive relations to operate.

Beyond environmental relations I want to draw out three orders of relations which are classified on the basis of their interactivity and thus on their organisational capacity. They are all causal relations:

First order relations: directly causal, feedforward
Second order relations: circular causal, feedback
Third order relations: mutually causal, interaction

First order relations: Feedforward

Where the environmental relations of position, adjacency, relative size or power, etc., have any causal consequence it will generally be through their enabling of sub-atomic level physical forces as well as more macro-level properties/effects such as pressure, kinetic energy (eg temperature), frequency and so on. These are all essentially feedforward relations - their actions impact on other similar scale relational complexes as objects in what is, essentially, a linear process. Feedforward offers no situation in which the object takes into account the degree of impact of its relations with some other object affording it some kind of "information" as difference relations by which it can regulate its action.

Second order relations: feedback

Feedback relations are the means by which a system of some complexity is enabled to have some sort of information about its internal conditions and about its relations with its environment. When an action is productive of an impact back onto the originating entity then this relation will provide
feedback and the originating entity is enabled to regulate its output so as to, for example, more gently enfold the object of its intentions.

Feedback relations within internal processes or with the external environment enable a system to be self-regulating and to maintain itself in the environment as a novel system self-contained within the (chemical) soup of its environment. By permitting self-maintenance they allow the system to preserve its coherence and to be an integrated individual as an emergent "object". It is the relations of the system with its environment and its internal self-regulation, afforded by feedback, which make the system possible and by which it emerges from the soup as a distinct and distinguishable entity. They also permit the possibility of intentionality (Jones, 2000).

There are a number of different identifiable types of feedback relations based either on the function of a comparison generating an error value (Weiner, 1948) or on the re-entry of processed input (Edelman, 1989).

A: With error values

1: Feedback in which a sample of the output is fed back into the input as a direct modulation of the input value. Negative feedback produces an inhibition of the system and is what provides stability in an amplifier. It is what helps a system survive perturbation. Positive feedback may cause a non-linearity in the system producing oscillation or hysteresis (step functions) in the system. Positive feedback may also induce resonance in a system. There are well-understood conditions under which this resonance can occur (e.g., feedback oscillators and resonant filters in electronics) yet it is a perfectly good example of a weak emergence. Combinations of negative and positive feedback will make this resonance a dynamic process in which carefully controlled conditions can produce interesting emergent objects. There is a very interesting setup that can be produced with a video system in which careful arrangement of the camera pointing at a monitor displaying the output of the camera can produce clearly emergent patterns which are often described as 'having a life of their own' (Crutchfield, 1984; Jones, 1979), (see Fig.1).

2: Feedback in which further processing stages have been added to the system so that its output is filtered or otherwise modulated before it is returned to the input stage. These are the kind of feedbacks which could be used to provide emphasis of some particular aspect of the input. In attentional processing this kind of feedback would allow the system to focus on some particular segment of the range of inputs it receives and could well be the kind of feedbacks that are involved in the thalamo-cortical loops system described by (Newman, 1997; Churchland, 1995, ch.8).

3: Feedback with comparison to a norm or intended outcome, generating an error value which is returned to the input stage. This is the kind of control feedback that could be utilised in the successive approximation process that is reaching for an object. Each stage of the articulation of the arm provides a feedback error value narrowing the discrepancy between current and intended position. This is the kind of feedback that can be called goal-directed.
B: Without error values

1: Unguided learning: This is feedback where the output behaviour of some system becomes entangled with input for itself but without regard for any goal state or intended condition, i.e. without comparison. Thus it occurs when a known goal state is not available and the system has to make its own way categorizing as it proceeds. In a constructivist interpretation of the world, much of our categorization of input stimuli cannot have developed in comparison with a pre-existing norm but must have been made according to a series of recurrences of events reinforcing certain ways of viewing the situation as against other ways of viewing the same input. Edelman calls this kind of feedback re-entry and argues that it is re-entry that by its “correlation of selective events across the various maps of the brain” allows an animal to partition the world into objects and events (Edelman and Tononi, 2000). The diversity of languages in the world could only have developed in a manner free from the imposition of error values in regular feedback interaction with the environment inanimate and animate.

2: Binding: Edelman uses the concept of re-entry to explain binding (as “spatiotemporal coordination”) between sensory modalities in which a reciprocal mapping between the receptive fields of the modalities serves to reinforce a connection between them when there is simultaneous stimulation of the modalities as there often is in real-world interaction. (Edelman, 1989, p.62, Edelman and Tononi, 2000, p.85). He also suggests that re-entry produces the interconnection of events and categories with “value”-producing processes that construct scenes which are related to the learned history of the animal (Edelman and Tononi, 2000, p.109).

3: Memory: Possibly the most important of the consequences of feedback networks, particularly in biological and neural systems, is that the propagation delay through the system and the resonance effects that the system will contain produce something which could easily be considered short-term memory. It is very likely that that slightly smeared experience of the present that we have as James’ “specious present” or as working memory (Barrs, 1997) is produced by this feedback structure, and of course working memory is fundamental to most conceptions of consciousness.

4: Self-reflection, reflection on what has gone before, on what we have experienced; The whole ability to reflect on what is occurring in comparison to things which have been experienced previously, categorized and learned as history is a function of this kind of re-entrant processing coupled with memory and possibly with the error-value generating processes that allow us to evaluate the effectiveness, say, of some act.
It is these kinds of processes that are active in all kinds of biological systems. When a system is complexly structured enough and this complex structure has adequate organisation there will be a massive array of internal feedback relations. At the same time this system has to be operating in some sort of an environment and given that complete isolation or independence from this environment is most unlikely there will be a potentially similarly massive array of possible and actual external relations with the world. It is the open system nature of (emergent) organisms that promotes their coherence/integrity by ingestion and sensing enabling boundary development and self-maintenance.

The kinds of relations that might be called sensing and probing, where there are other systems of adequate complexity in the environment, may lead to mutualistic relations and bring about communication. Any of these processes will indicate some sort of primitive intentionality in the system.

**Third order relations: mutualistic feedback relations, interactions, conversation**

Third order organising relations are the mutual relations of interaction between entities. An entity A in an environment and at least one other entity B also in that environment may influence each other's behaviour by their own productions, A influencing B and B reciprocally influencing A. These are the relations of social interaction but they are also the relations obtaining in the emergence of a multi-celled organism from a soup of single cells which have evolved into various forms of symbiosis and interdependence of, for example, their metabolic regulation (Jones, 2001).

People in interaction learn about each other, they teach each other (Pask, 1962, p.302), they influence each other, they may compete for stuff or information, they may co-operate to gather stuff or information. It is these processes which bind a collection of individuals into a society, and it is the individual's growth into an environment in which these mutualistic relations operate that helps produce a coherent, conscious, language-using individual capable of operating in a society.

Language development is the primary social interaction. It is what enables us to function in a society and to interact at many of the levels that do so with others. It is by a mutual interactive feedback process that we learn to speak, through exposure to others' use of language. We do this by modulating the babbling that we produce as infants according to the sounds that we hear around us that are presented to us in the interactions basic to the child-parent relationship. As we make sounds that we mould to mimic what we hear, those sounds (as phonemic sequences) are heard by others (some of the time anyway) who then repeat, correct, respond and otherwise guide us to better approximations of the conventions of language in the culture into which we are born.

**VI**

What I call here second-order and third-order relations show forms of relational process that can bind a system in a dynamical coherence which presents it as "emergent" in the sense, respectively, that a cell is emergent from its metabolism and that a culture is emergent from a collection of individuals. The coherence or integrity of a living system and its apparent reduction of entropy are a function of its open-system nature (von Bertalanffy, 1968; Oparin, 1961, pp15-16). The maintenance of a state of reduced entropy, ie, the maintenance of its state of organisation, is done by the intake of energy (either directly, as eg: sunlight in photosynthesis, or indirectly through ingestion) from its environment. This intake helps to maintain the chemical metabolism of the internal (membrane bounded) system through the production of proteins and energy carrying...
molecules such as ATP, but it also produces metabolic waste products which may be deleterious for the system. These wastes will be excreted out through the membrane completing a loop (circular) relationship with the environment. I suggest that these outputs/excretions may in fact be the basis for the development of mutualistic (third-order) relations (Jones, 2001; Pachepsky et al., 2002). This kind of process provides an example of how one might get from second-order to third-order relations: through this open-system characteristic that is necessary for the maintenance of order under dynamic conditions. The flow of impressions into (by perception) and out of (by production) ourselves as conscious beings is the analogue for this open-systems character when we consider consciousness. Perceptions and productions are the primary elements of exchange with the environment that keep us integrated as conscious beings capable of interaction with other entities and processes in the world of matter and ideas in their embodiments in the world.

**Emergence of Consciousness**

Consciousness is very much that activity of organised systems to which the concept of radical emergence is applied, especially by those who wish to claim it as being non-physical while accepting that conscious beings are physical beings. Others, (van Gulick, 2001; Silberstein, 2001), think of it as being, somehow, a non-reducible emergent property of organised biological systems. Non-reductive explanations of consciousness deny that we can reach a suitably reductive explanation of the physical basis for consciousness while denying that form of radical ontological emergence in which a mental stuff (information in (Chalmers, 1996) sense) emerges within a physical system. However, my point here is that consciousness does indeed have a reductively physical basis and that the so-believed mental contents are simply aspects of the processes of its physical constitution.

So, what are the processes of relations which enable a system to show properties indicating that it is conscious? Here I again invoke the concepts of feedback (second order) and mutualistic feedback (third order) relational processes. Briefly, a conscious system will be (a) sensitive to its environment and its internal context, (b) communicative, (c) attentional and (d) self-regulating both in directed attention and in interaction. The neurophysiology that allows the complex feedback relations (mentioned above) to operate and provide much of the recognizable aspects of consciousness, especially those involved with attention and awareness, involves at least a considerable degree of reciprocal pathways that run between the cortex and the thalamus and other basal ganglia (Edelman, 1989; Newman, 1997). One must then add mutualistic or third order relations so as to afford the conscious entity any kind of access to social meaning. The intra-brain re-entrant structures allow the system to be able to experience its world and extract meaningful information from it but the mutualistic relations allow it to co-ordinate its experience with others giving a measure of consensual meaning and the cohesion of a societal engagement.

In an individual most of the sensory systems of the brain run via the thalamus relaying sensory data to appropriate cortical processing regions which then return to the thalamus some sort of information relating to that sensory data. This re-entrant data, the feedback, may well allow the thalamus, via the putative gating function of the intra-laminar nuclei (Bogen, 1995), to selectively emphasise and de-emphasise certain aspects of the sensory data providing a measure of control over what the system is paying attention to (Newman, 1997). The very fact of the loop structure introduces delay through the system, and - especially if the putative 40Hz oscillations are related to synchronizing sensory and reflexive processing channels for binding and the unity of the perceived
world - this delay will be well within the range of several hundred milliseconds, providing a sort of smeared out present and, as the information in these loops continues to reverberate, some contribution to short term memory. There are also many other structures for which complex feedback pathways also operate, though I suspect that the thalamo-cortical loops system is among the primary pathways of the basic requirements for consciousness such as attention.

In a conscious entity sense-data becomes information providing patterned and dynamically structured form to the network of interacting subsystems. The information flow reverberating through the thalamo-cortical system establishes relations among various processing sub-systems which allow the system to know about its own contents. This knowledge of itself is what is necessary for it to be successfully self-regulating. The insertion of future oriented planning and desire, through frontal cortex, and emotion processing, modulates and directs the intentionality that must appear when a system has any form of directed interaction (which can be as simple as food gathering) with its environment. When the system contains information about itself or about its environment and that information is, or becomes, important or useful, or in the more sophisticated species simply interesting, then that information can be said to be of significance to the system and it is significance which forms the basis for meaning. Re-entrant knowledge of itself also allows an entity to be conscious of the world in its experience of the world’s qualities, thus possessing qualia and subjective experience. The system is a subject to itself. The system in knowing itself is experiencing itself and qualia are the biologically embodied states of its internal neural phase space (its internal Hilbert Space) of that dynamic information which it knows directly from the inside, by being the physiological space in which all this goes on.

Reduction revisited
It is my contention that reductive explanation is, in principle, possible in all of these conditions that we commonly think of as emergent. Nevertheless such reduction tends to obscure the forest not simply by a description of the trees but by the demand for a description of the quantum processes that occur in the constructions of the atoms and then the molecules and then the amino-acids and the proteins and then the cells and so on up to the ecology of the forest. Strict reductionist explanation is thus rather wasted, tedious if not intractably difficult to do and not very useful. It is by an analysis of the levels of organisation in the emergent structure and the use of reductions that are appropriate to each level that we can build up explanation of the apparently emergent object or property. Thus "emergence", used as an explanatory principle, is a kind of shorthand. Useful explanations of a system need to actively account for the role of the relations among the parts at each sub-level, and this can have the great value of opening up the nature of mechanistic explanation, rendering it relevant in understanding the dynamics of process. As Holland comments: "When we can formulate macrolaws that describe the behaviors of emergent phenomena (for instance, the laws of chemical bonding) we gain greatly in comprehension, whether of a model universe or a real one." The point being that "we do not expect the emergent phenomena we observe to have simple descriptions in terms of the underlying laws [of physics]. Indeed, … we search avidly for simplifying macrolaws" (Holland, 1998, p.189).

In conclusion
Though it is convenient to talk of emergence as though it were in itself a mechanism by which an object at some level of organisation in the world is rendered through the integration of an
ensemble of parts, the problem is that seeing it as a mechanism in itself gives it a mysterious nature which is often thought of as being irreducible. Or, if the emergence is not accorded the status of mechanism, then the hierarchical integrations themselves are seen as irreducible. Neither of these need be the case as I have argued here and the idea of emergence as a mechanism dissolves when the kinds of relational dynamics which operate to bring about the next layer of integration are fully described.

Reductive explanation is, in principle, possible in all those conditions that we commonly think of as emergent. It is often incredibly difficult, but that is not an excuse for saying that it isn’t there. Nevertheless such reduction tends to obscure the forest not simply by a description of the trees but by the demand for a description of the quantum processes that occur in the constructions of the atoms and then the molecules and then the amino acids and the proteins and then the cells and so on up to the ecology of the forest. Strict reductionist explanation is thus rather wasted, tedious if not intractably difficult to do and not very useful. It is by the analysis of the levels of organisation in the emergent structure and the use of reductions that are appropriate to each level that we can build up explanation of the apparently emergent object or property.

In other words if we are going to explain emergences then we have to develop explanations which acknowledge the levels or orders of the hierarchy of organization and these have to be contained within each level so that to completely explain some complex organism we must carry out a series of explanations each of which amounts to a reduction of one level into the level of its constituents and their organizing relations at that level. In turn the components, in that they are also wholes, have to be explained from within the frame of their own level, working down to the ultimate micro-physical components in a series of steps rather than trying to do what must rapidly become intractable and explain the most complex social organisation of people in terms of the behaviour of quarks and photons.

I have argued for a physical basis for all ontological forms of emergence and consequently appear to be denying the possibility of a great wonder of the universe: its meaningfulness. But I want to suggest here that in fact I am arguing for an even greater wonder and that is that the physical, material universe itself is capable of conscious existence through its interdependent accumulation of complexity. In other words what we normally think of as "mental" is in fact a characteristic of complexly organised forms of ordinary matter and requires no miracles for its development.
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