Is Relational Physics the way ahead?

Brian D. Josephson (University of Cambridge) and Mrittunjoy Guha Majumdar (Indian Institute of Science)

ABSTRACT

This paper develops an approach to fundamental physics that may be termed relational physics, involving ideas similar to those developed in the context of biology by authors such as Rashevsky and Rosen, and in the context of physics by Barad. In his relational approach, Rosen argued that while, on account of its complexity, the state of an organism cannot be fully prescribed in a meaningful manner, biologists are able nevertheless to deal meaningfully with the components of such a system, their interrelationships, and their organisation, and thereby (as exemplified by the creation of a vaccine on the basis of biological discoveries) investigate the workings of an organism in ways that are productive rather than being purely theoretical or philosophical.

Translation of this strategy into the world of physics can be achieved on the basis of the idea that the components subject to analysis in the physics context are dynamical systems rather than the chemistry-based ones of traditional biology, while the mathematical aspect is postulated to develop by similar mechanisms to those involved in the development of mathematics by mathematicians. This would be the way that universes subject to physical laws would emerge, in accord with Wheeler's idea that natural law is the outcome of 'observer-participancy', but with the additional constraint that such emergence has to have a life-supporting character, providing a strong constraint on both the forms of universes and their contents.

(this is a preliminary draft, and comments would be welcome)

INTRODUCTION

This paper develops an approach to fundamental physics that may be termed relational physics, based upon similar ideas developed in a biological context by authors such as Rashevsky and Rosen (1991), and in the context of physics by Barad (2006). Traditional physics is based on *equations* prescribing the time dependence of a given system, but as noted by Rosen, and by Josephson (1998) this is problematic since such equations cannot be utilised without having an appropriate specification of the state of the system. Traditional physics evades this difficulty by confining itself to the investigation of just those situations where such specification is available, but it may well be a consequence of such constraints that important aspects of nature are omitted from physicists' investigations, with the implication that new approaches might lead to new physics.

In fact biology, particularly with studies such as those of coordination dynamics (Kelso 1995, 2013), biosemiotics (Barbieri 2008), the study of the role played by meaning in biological systems, and Rosen's relational biology, does use tools different to those of physics, focussing on the diverse roles played by *significant units* or synergies, instead of trying to reduce everything to a single universal 'theory of everything' as in physics. Given the existence of intriguing parallels between the quantum domain and biology (Conrad et al. 1988), one is led to consider whether an approach to physics similarly involving consideration of units and their interrelationships (as indeed has been discussed by Barad) might give us a deeper understanding of reality than the traditional ones where the problematic 'state of the system' plays a central role.

The essential question is how can physics be reduced to biology whilst retaining its mathematical character? Our answer is in principle a simple one, based on the presumption that the units involved in the analysis are dynamical systems, interrelated to each other in the same way that are the units that characterise biological systems. Such systems could be subject to detailed analysis. Two particular factors appear to have an especially important role in explaining the way biological systems work, namely *coordination,* with its synergies (complexes acting as a single coherent unit), and the *modelling process* discussed by Rosen. As discussed here in detail, these two main factors working in conjunction with each other can credibly account for the emergence of the organised complexity characteristic of biological systems, with its associated functionality. Additional insights come from the concept of a flowchart, and the Circular Theory of Yardley (2010).

Such a picture is consistent with Wheeler's idea (Wheeler 1983) that participatory observers are responsible for the emergence of physical laws, rather than such laws being applicable for all time, but our approach has the capacity to account for the emergence of physical laws in detail rather than just qualitatively, treating it as an evolutionary process similar to that of biological evolution involving a collection of phenotypes (characteristic behaviours), each associated with its own specific mechanisms.

In our more detailed analysis, we discuss first organisation and the role played by encoding in that process, and then the way coordination between different units is able to lead to the complicated functionality observed in nature. The connection with physics is then discussed on the basis of the understanding that mathematical activity (that is to say what mathematicians actually do) is subject to similar principles to those discussed in this context, with the implication that nature can in principle develop a mathematical aspect in the same way that working mathematicians do, such a process having also a biological component, in that the biological context helps to determine which mathematical activities will be performed in any given situation.

HOW ORGANISATION WORKS

What exactly is organisation? Organised systems work efficiently (whatever that may entail), in a way that disorganised systems do not. In Rosen's picture, the modelling process plays an important part. Two interconnected systems are involved in such a situation, namely a system specifying what should happen, and a second system that acts in accord with such specification. However, the connection involves a two-way process, in that the first system takes into account the activity of the second, adjusting its specification in accord with what is happening.

The situation of two separate systems working in harmony with each other is a special case of what Yardley refers to as oppositional dynamics, and can have a complex character, as can be seen through the related concept of protocol, which in the context of computing consists of a specification of how a system should function in order to behave in a specified manner. An example is the world wide web, whose functioning is governed by a complicated collection of procedures, such as the use of a URL to specify a web page, combined with a mechanism that causes the web page thus specified to be accessed when a user clicks on a link. The web works properly as long as web browsers, servers and web pages all conform to the protocol. Conversely, in the context of emails, Microsoft's Exchange mail servers fail to observe entirely the official protocol for email systems (IMAP), leading to problems when emailing other users.

Computing systems work efficiently on account of the activity of their designers, but nature appears to be able to create similarly effective mechanisms, an instructive case being that of natural language with all its complexity. The existence of such mechanisms in general can be understood on the basis of the fact that a two-way process of the kind discussed above is involved, with the organising system observing what happens in the activity it is responsible for, comparing it with what some protocol asserts should happen. Here, in effect, some prescriptive signal activity is decoded, and then encoded again, in some cases reinforcing the original. Normally this 'echo' will have little resemblance to the original, but in some cases it will be similar and the process can repeat, while furthermore in some cases the system as a whole will settle down to an *attractor* that repeats itself precisely, yielding a stable state of affairs.

However, this two-system situation is a special case. Coordination dynamics, deriving from a combination of experiment and modelling, deals with more complicated situations, in general involving more than two interacting entities. The reader is referred to Kelso's review of coordination dynamics (Kelso 2013) for a detailed account of the way synergies constantly form and reform depending on the context.

We focus in the following on the modelling concept, whereby the coordination process is accompanied by the emergence of models of various kinds. Through the emergence of models by the coding-decoding mechanism discussed above, situations arise where a complex of information or signs, associated with the synergies that come and go, constantly shapes the system in which it is embedded, while searching for new forms of stability. Such a situation can usefully be characterised (Guha Majumdar 2020) as one involving *self-selected fluctuations*, with potential instabilities giving rise to fluctuations that become restrained through the discovery of organisational mechanisms of various kinds.

An attractive feature of this hypothesis is that it can account for the complexities of language, emerging as the consequence of a form of evolutionary process. An approach to language known as systemic grammar (Bavali and Sadighi 2008), supported by a successful computer simulation of language due to Winograd (1972), hypothesises that languages can be modelled as collections of very specific functional units, each of which can serve the purposes of language in particular situations. A language can thus evolve through users coming to discover new organisational mechanisms, some of which become adopted by others as they develop their own copies of the units concerned in the given situation.

FLOWCHART MODELS

A useful way to represent complicated activity is that of the flowchart, which in the context of computing indicates the sequence of processes in a computation, the options available at various times, and the conditions determining the choices made. Seen as a form of map, a flowchart allows inferences to be made regarding the outcome of a given process, by following through the various possible routes. While the normal context of flowcharts is that of computer software, where a flowchart representation a set of instructions in visual form, it is equally applicable to behaviour in general, and can thus help to explain complex behaviour such as that of language, each functional unit having its own flowchart accounting for its behaviour. The idea can be illustrated by the example of the combination of question and answer that can as a whole be characterised as ‘answering a question’. At a level of detail, the questioning and answering involved are completely different though related processes, and yet the process, viewed as a whole, is the same for both the individuals involved, namely ‘a question is being answered’. Coordination works at one level because both individuals see what is happening as the same entity, while if on the contrary they had different ideas as to what was happening then effective communication would not occur. Both having the same idea as to what is happening is an aspect of the whole process, and can develop similarly by trial and error.

Yardley’s Circular Theory would appear to be saying something similar with its ‘oppositional dynamics’. Central to it is the idea of ‘two as one’ and vice versa, referring to the way two entities can merge into one or vice versa as a physical process, which can be seen as a system being at a critical point. But here the ‘two’ are characterised as involving a line being the diameter of a circle, which can be understood as the system having a degree of freedom corresponding to the direction in a plane or as a phase variable. Yardley is thus claiming that a special type of critical point is involved, involving a triad, the third element being the control system that determines not only the criticality but the additional degree of freedom akin to the phase of an oscillation. Given that phase relationships and phase locking have an important part to play in coordination dynamics (as in the HKB model that accounts for various aspects of stability), Yardley’s ideas concerning relationships, not as yet developed in mathematical terms, may well be well worth exploring further.

RELATIONAL PHYSICS

The question then arises as to whether such concepts can account for the emergence of physical laws in the manner envisaged by Wheeler. We address this issue on the basis of the idea that mathematical activity is not purely the preserve of mathematicians, but something more general. In this connection we note that, as discussed by Penrose (2006), mathematics originates, as does other human endeavours, in the attempt to characterise aspects of reality in useful ways. For example, Euclidean geometry arose from the attempt to characterise regularities concerning objects in space, while arithmetic and algebra arose from activities involving counting, and over time other mathematical traditions come into existence similarly. What makes mathematics different from other human activities is its ability to *prove theorems* on the basis of axioms, which possibility was discovered by mathematicians such as Euclid and Pythagoras. Mathematics, as discussed by Penrose, develops step by step as mathematicians attempt to develop extensions of existing systems, as for example in the way real number mathematics developed into into the mathematics of complex numbers by postulating an additional square root of minus one, which led to the emergence of an extended axiomatic system with remarkable properties of its own.

Our hypothesis now is that nature itself can develop and utilise similar mathematical capacities, an idea that while it may seem strange is not logically impossible. Let us therefore consider the consequences, the question being how such abilities would develop. Such activity can be expected to be undertaken by the systems concerned for its *utility*, rather than being simply being carried out for its own sake. Systems such as those of complex numbers can have their utility on account of the variety of *facts* available in such a system. The issue is therefore what kinds of facts might be relevant for life based, as postulated, on dynamical systems. Of particular relevance here are processes that might be able to extend the domain over which a particular process would be possible, something related to the idea of *invariance* under particular transformations. Such invariance can be extended in turn to group structures, where transformations combine in well-defined ways. Connected with this is also the concept of a *manifold*, involving specific degrees of freedom with their own mathematical properties. Penrose notes in this connection the possibility of manifolds being created step by step by joining together portions of a manifold, a physical process.

Our general picture envisages some primordial observer working away in the manner described by Wheeler, but in addition using mathematical systems intelligently to define and then create a supportive universe, which would automatically account for the anthropic character of the observed dynamical laws. Furthermore, having determined how to create such a universe, the observer or observers would be in a position to define what processes should occur in that universe, and their outcomes.

CONCLUSIONS

The above has discussed in some detail how a unification of biology and mathematics might be achieved, leading to what might be called relational physics, based simply on the idea that the processes whereby mathematics as such comes into existence in the human context might equally occur in the context of dynamical system, leading as a result to a universe of the kind that we find ourselves in. While clearly much work is needed to follow up these ideas in detail, the combination of ideas developed in the above would seem sufficient to allow a programme of research on these lines to be initiated, with the likely prospect of creating a rival to the existing 'theory of everything' approach.

ACKNOWLEDGEMENTS

We would like to thank J.A. Scott Kelso and Ilexa Yardley for insightful discussions.

REFERENCES

Barad (2006), *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*. Duke University Press.
Barbieri (2008), *Biosemiotics: a new understanding of life*.
Bavali and Sadighi (2008), *Chomsky's Universal Grammar and Halliday's Systemic Functional Linguistics: An Appraisal and a Compromise*.
Conrad et al. (1988), *Beyond Quantum Theory: A Realist Psychobiological Interpretation of Physical Reality*.
Guha Majumdar (2020), *Unified • − Field: How Self-Selected Fluctuations can underlie Reality*
Josephson (1998), *Limits to the Universality of Quantum Mechanics*.
Kelso (1995). *Dynamic Patterns: The Self Organization of Brain and Behavior.* MIT Press.
Kelso (2013), *Coordination Dynamics*.
Penrose (2006), *The Road to Reality: A Complete Guide to the Laws of the Universe*. Random House.
Rosen (1991), *Life Itself.* Columbia University Press.
Wheeler (1983), *Law without Law*.
Winograd (1972), *Understanding Natural Language*.
Yardley (2010), *The Circular Theory*.