Methodology, Theory and the Advance of Science

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ABSTRACT

A science (or a paradigm within a science) is a product of a particular way of approaching the problems of nature. This paper is concerned with the science behind the existence of paradigms: why do they exist, and what are the mechanics of change? Of particular interest is Bohr's question: does quantum mechanics encompass life or not, the answer being that it depends on how one wishes to interpret the question. An argument of Conrad et al. shows a way in which quantum mechanics might be inadequate, the argument being equally relevant in certain other contexts that are discussed.

Introduction

This paper is concerned with the intimate relationships between research methodologies and scientific theories, in particular fundamental theories of physics. The commonly accepted foundational theory in physics is quantum theory, but what is actually meant by the quantum theory changes over time, as a result of new discoveries and new ideas. These changes can be linked to changes in the mindset, i.e. the collection of beliefs or paradigm, of the scientific community. With any investigation, scientific or otherwise, one starts by gathering information, and then discovers regularities that can ground new concepts and new modes of description, some of which may consist in a specification of the *state* of the system of interest. This may lead on to the formulation of general laws, which in physics may take precise mathematical form. These latter developments involve *public modes of description*, as opposed to personal modes (which can have their own extra-scientific validity). In science, such precise theories may for a time be regarded as the ultimate, universal, theory, until phenomena are discovered or noted that cannot be fitted into the existing framework, at which point new concepts and new theories have to be introduced to make progress.

The fact that apparently satisfactory theories can endure, and be considered satisfactory, over a substantial period of time, is itself a matter of interest. In the relevant era of science, the methodologies utilised explore only some subset of the set of all conceivable possibilities and it is that subset, which is in some sense a natural subset pertaining to the conditions of the time, to which the models of that era, based on particular forms of description, apply. After the change, when a more advanced theory becomes available, it becomes possible to understand the nature and reasons for the existence of the natural subset (e.g. that it has as its basis all velocities being small compared with the velocity of light, or lengths being large compared with atomic dimensions, etc. etc.) and why the more primitive theory should apply to it, which accounts may depend on simplifying restrictions such as ones related to self-organisation or symmetry. The developments that lead to a new era of science involve in some way breaking out of such constraints, which result from new technologies, or the application of existing methodologies in new situations. In some cases, the new phenomena may be phenomena that have already been observed and reported, but which were ignored or dismissed because they did not fit the existing paradigm (cf. Josephson 2004).

Current developments in quantum theory suggest some sort of crisis (or at least significant interpretative ambiguity) in fundamental theory at this time. The so-called Standard Model makes very specific predictions that accord well with experiment, but does not incorporate gravity. The attempt to include gravity in an elegant way led to string theory and M-theory, and the hope had been that these theories would explain the standard model. But it turns out that the more advanced theories do not imply a unique physics, which can be equated to the presence of a significant gap between abstract theory and concrete experiment. This gap implies in turn that many alternative theories might exist that would equally well fit the Standard Model. Had string theory led uniquely to the Standard Model, one might have justifiably claimed that all theories with this property were equivalent, but this state of affairs does not accord with the situation that we find.

The Irreducibility of Life

The idea suggested above, that a particular point of view constrains the science, is illustrated by a argument made by Niels Bohr (1958), discussed in some detail by Josephson (1988), regarding the applicability of quantum mechanics to living organisms:

> *"The recognition of the essential importance of fundamentally atomistic features in the function of living organisms is by no means sufficient, however, for a comprehensive explanation of biological phenomena, before we can reach an understanding of life on the basis of physical experience. Thus, we should doubtless kill an animal if we tried to carry the investigation of its organs so far that we could describe the role played by single atoms in vital functions. In every experiment on living organisms, there must remain an uncertainty as regards the physical conditions to which they are subjected, and the idea suggests itself that the minimal freedom we must allow the organism in this respect is just large enough to permit it, so to say, to hide its ultimate secrets from us".*

Against this claim, it may be argued that we no more need to know precise details of the atoms in an organism in order to be able to predict its properties than we need to know where the atoms of a fluid are in order to be able to predict its viscosity. However, in the case of a fluid we can write down an appropriate model simply on the basis of knowledge of the temperature, pressure and chemical composition. This is not the case for an organism, which is particularly problematic because it is an open system and its composition is not fixed. And it is certainly possible in biology for events at the quantum level to have important consequences, such as whether a particular individual develops cancer or not.

Related is the fact that with the systems typically studied in physics, system fabrication is in essence a matter of following a recipe starting from well-defined starting materials, whereas life cannot be synthesised by such recipes, the lack of a recipe being related to the above consideration of not knowing precise details of the state of the organism, which details may significantly affect the viability of the organism concerned. Nature has found out how to get the details right by a process of trial and error, a process similar to the situation of an industrial process, where many copies of a device are made and only the ones that function effectively are kept. In such situations, the specification can be said to be indirect (in terms of functionality and the processes), rather than directly in terms of the state of the system; in the terminology of Baas (1994), we have observational emergence, not deducible emergence. Biosystems are, from the physicist's perspective, anomalies: systems that refuse to lend themselves to the specifications that the usual paradigm uses.

Is this problem a fundamental one, or merely pragmatic? An argument due to Conrad et al. (1988) suggests that the situation may not simply be a case of inability to characterise the system in direct terms. The authors illustrate the point by contrasting two approaches to the characterisation of a classical gas, the statistical approach of statistical mechanics, and the dynamical approach involving consideration of the trajectories of individual molecules or atoms. The two approaches yield very different kinds of physical law, despite being accounts of the same physical system. The difference matters in situations where our measurements are sensitive enough that individual trajectories are an issue. In the same way, it is suggested, quantum mechanics may (as in the analogous causal approach of Bohm) be a statistical account, dealing with statistical averages, while biology in contrast focusses on individual organisms where particular aspects (involving the functionality) may be better defined than in the statistical account corresponding to quantum mechanics. The point at issue here is that averaging typically introduces certain approximations that may be invalid when dealing with individual instances. In this perspective, our special systems (living systems) are anomalies that may be seen as deviations from the norm that are too severe for the approximations that are valid in the case of comparatively small deviations to be applicable.

Other Anomalies: Mind. the Paranormal, and Music

The word anomalous, from this perspective, has a double meaning. From one point of view, anomalies do not fit the laws of nature and thus must be considered the result of errors of some kind. The alternative view, justified by the present discussion, is that anomalies merely involve situations that are too extreme in some way for the approximations that one normally takes for granted to hold. But, as in the case of life, such anomalies can become self-sustaining and lead to a new realm of phenomena.

In the final part of this paper I will discuss various other situations that may fit in with the latter concept. The first follows discussions of Stapp (2005), who rejects the many-worlds interpretation of quantum mechanics as being problematic, and invokes mind, 'asking questions of nature', being the fundamental mechanism underlying state vector collapse. In the present perspective we view mind, and its concomitant meaningful information, as additional factors needed to describe the mechanics of some emergent, self-sustaining process involving more precision than is encompassed by the standard statistical descriptions of quantum mechanics.

This can be taken further, as was done by Josephson and Pallikari-Viras (1991) and by Valentini (1991), by taking into consideration the non-local aspect of quantum mechanics. These authors showed that under the assumption of a deterministic underpinning of quantum mechanics, violations of the usual rule that, despite the non-locality implicit in quantum mechanics, information cannot be transmitted at a distance, an occur in consequence of the violation of a certain statistical assumption, whose validity equates to the standard quantum predictions. Such a possibility might be exploited by life in paranormal capacities such as ESP (telepathy), for the existence of which there is considerable experimental evidence (Radin 1997).

As yet, our understanding of these matters is very rudimentary. What would be needed for fuller understanding is a fundamental account of the influence of information (in a mind-system) upon matter. The situation is complicated by the fact that in a biological situation, the detailed significance of information, as for example in the significance of a specific neural firing pattern, is context dependent. A unification of the mind aspect and the matter aspect of nature would help to resolve these issues.

Finally, some comments on the possibility of music functioning as a special code. Josephson and Carpenter (1996) argued that the conventional attempts to explain music appear inadequate, and that an alternative would be for the intelligence of the mind to consist of a collection of adaptations that music could invoke selectively, in the same way that in the usual biological context particular molecules invoke particular biological adaptations selectively. The specificity of the effects of music appears not to be explicable on cultural grounds or ordinary evolution, and may thus be a universal characteristic of mind in its own realm.

References

Bohr, N., 1958, Atomic Physics and Human Knowledge, Wiley, New York.
Baas, N.A. 1994, *Emergence, Hierarchies and Hyperstructures*, in Artificial Life III, SFI Studies in the Sciences of Complexity, vol. XVII, Ed. C.G. Langton, Addison-Wesley, 515–537.
Conrad, M., Home, D. and Josephson B. 1988, *Beyond Quantum Theory: A Realist Psycho-Biological Interpretation of Physical Reality*, in Microphysical Reality and Quantum Formalism, Vol. I, eds. G. Tarozzi, A. van der Merwe and F. Selleri, pp 285-93, Kluwer Academic, Dordrecht (http://www.tcm.phy.cam.ac.uk/~bdj10/papers/urbino.html).
Josephson, B.D. 1988, *Limits to the Universality of Quantum Mechanics,* Found. Phys. 18, 1195–204 (http://www.tcm.phy.cam.ac.uk/~bdj10/papers/QMlimits.html).
Josephson, B.D. and Pallikari-Viras, F. 1991, *Biological Utilisation of Quantum NonLocality*, Found. Phys., **21**, 197–207 (http://www.tcm.phy.cam.ac.uk/~bdj10/papers/bell.html).
Josephson, B.D. and Carpenter, T. 1996, *What can Music Tell Us about the Nature of the Mind? A Platonic Model*, in Toward a Science of Consciousness ed. Stuart R. Hameroff, Alfred W. Kaszniak and Alwyn C. Scott MIT Press.
Josephson, B.D. 2004, *Pathological Disbelief*, lecture given at the 54th Meeting of Nobel Laureates, Lindau, http://lenr-canr.org/acrobat/JosephsonBpathologic.pdf.
Radin, D, 1997, *The Conscious Universe*, HarperEdge, San Franscisco.
Stapp, H.P. 2005, *Quo Vadis Quantum Mechanics? (The Frontiers Collection)* ed. Elitzur, A., Dolev, S., and Kolenda, N., Springer, Berlin and Heidelberg.
Valentini, A. 1991, “Signal-locality, uncertainty and the Subquantum H-theorem”, Phys. Letters 156, 5–11 and 158, 1–8.