Non-classical computation and the computationalist stance towards the natural and cognitive sciences

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In recent decades a number of the natural and cognitive sciences have taken what might be termed a *computationalist* stance towards their domain of study. Such a stance consists of asserting/proving/assuming/showing that some phenomenon in the world has a computational aspect in the way that it functions, and then following through the consequences of this for the phenomenon. For example we might explain the mechanisms of how the phenomenon occurs in computational terms, or look at some of the constraints and limits of computation and see how they might explain limits to the speed or capacity of the phenomenon in question.

The area of study in which this has taken the deepest root is in cognitive science. This is seen most notably in the connectionist paradigm which asserts that the activity of mind is created solely by the functioning of the brain as a computer, and that such a mind could in principle be realised on any computational substrate. This paradigm is grounded in two main assumptions: the *functionalist* paradigm, which asserts that mind is solely a product of the function of brain-stuff rather than e.g. what it is made from; and the *computationalist* paradigm, which asserts that a computer is a sufficient medium for the realisation of the activity of mind.

Whilst much study and criticism has been made of the functionalist assumptions that underly connectionist modelling, comparatively little attention has been paid to the computationalist assumption.

Similar computationalist stances have been taken in biology and medicine, though this is less well developed. The area where this is seen most strongly is in the analogy between DNA and computer memory; for example the maximum possible length of DNA sequences has been analysed in terms of the accuracy of the error-correction mechanism needed to reproduce "good enough" copies of the DNA sequence. A small amount of work has carried this computational stance through into physics, particularly in cosmology and quantum physics.

An interesting and important project is to consider what a general set of methods for applying this computationalist stance in different sciences might look like.

An important impact of the development of non-classical computation on this is the removal of the substrate-agnostic assumption that underpins classical computational science. If we instead assume that the substrate on which the computation happens can influence the computational capabilities of the system, then how does that impact on the computationalist stance?

One aspect how this might impact upon computationalist explanations of phenomena is in explaining modularity in natural systems. An example from the cognitive sciences is the way in which the mind delegates certain tasks from the brain to other somatic systems—for example in the phenomena accurately referred to as a "gut reaction". In terms of traditional computationalism this is inexplicable; if all computers are the same, why delegate a process to a second "computer" in the body. However if we are in a world where differently-substrated computers have different computational capabilities, we may be able to explain phenomena such as these more readily.

Overall my questions are these: how can we come up with a generic way of applying the computationalist stance towards scientific phenomena? And how does non-classical computation impact on this computationalist stance?