Extended abstract for Barwise Prize talk at APA 2021

How can minds like ours exist in a physical universe like ours?

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Venue

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After the talk this extended abstract was modified to provide additional information.
This document is accessible at:
https://www.cs.bham.ac.uk/research/projects/cogaff/misc/sloman-apa-2021.pdf
A video recording of the talk is available here https://www.cs.bham.ac.uk/research/projects/cogaff/movies/apa/

Note: All URLs in this document should be clickable – in most PDF viewers.

Overview

The talk presents key features of an intricate collection of ideas in biology, physics and chemistry that potentially have revolutionary implications for philosophy of mind, philosophy of science (including biology), and philosophy of mathematics including implications concerning the nature of consciousness, especially spatial consciousness, in many intelligent species. Human versions of the mechanisms underlying spatial reasoning in mathematics also have implications for philosophy/metaphysics of mind.

Number competences are not discussed. Many researchers who try to investigate innateness of number competences don't understand that a full grasp of natural numbers depends on understanding the necessary transitivity of one-to-one correspondence (a topological relationship), which does not develop until age 5 or 6 as Piaget discovered many years ago (Piaget, 1952). Spatial and temporal one-to-one correspondence are special cases. Spatial consciousness formed the basis of ancient human mathematical consciousness in topology and geometry centuries before Euclid, and even longer before the development of logic-based formal foundations for (some) mathematics.

Readers with no personal experience of discovering geometric constructions and proofs may find this tutorial by Zsuzsanna Dancso useful: https://www.youtube.com/watch?v=6Lm9EHhbJAY Without such experience it is impossible to understand what Immanuel Kant was talking about in his discussions on the nature of mathematical knowledge in *Critique of Pure Reason* (Kant, 1781). There are many more online geometry tutorials of varying quality. The worst ones merely present geometric facts to be remembered – like bad mathematics teaching in schools.

Long before spatial consciousness evolved in humans and other animals, related capabilities to detect and make use of spatial structures and relationships, must have evolved for use in ancient mechanisms assembling complex molecular structures during processes of biological reproduction, such as the processes of assembling a chick, or a crocodile, inside an egg, or a foal inside its mother.

Interactions between millions of relatively unintelligent termites can produce termite cathedrals with amazingly complex internal structures (https://www.nationalgeographic.com/news/2014/8/140731-termites-mounds-insects-entomology-science/).

Even more surprisingly, interactions between millions (billions?) of increasingly "intelligent" molecular assembly mechanisms during development of organisms (e.g. developments in a plant seed, chicken egg, or mammalian foetus), are crucial to construction of most of the visible organisms on this planet, including plants and animals. However, many (most?) of the details of the intermediate stages in such

construction processes are unknown, although evidence is accumulating in a variety of scientific and engineering disciplines, including biochemistry, embryology, and immunology, some of whose results are combined in the philosophical (metaphysical, meta-biological) project outlined here. The precise ways in which the sub-microscopic chemical assembly mechanisms are "intelligent" remain to be specified (Sloman, 2020).

As assembled structures become more complex, so must the mechanisms extending and combining those structures. This includes *(i)* increased size of the chemical structures used and produced, *(ii)* increased complexity of the information required for selecting and executing next steps in the construction and *(iii)* increased complexity of the biological/chemical mechanisms required. I suspect a lot more is known about such mechanisms than I am aware of, though its full significance for reproductive processes may not yet be known! The existence of newly hatched chicks, crocodiles and other self-assembled organisms is evidence for the existence of the mechanisms, but not the details of their operation.

These ideas suggest a biology-based interpretation of Immanuel Kant's theory of mathematical consciousness, based on evolutionary and developmental precursors of spatial consciousness in vertebrates, and some other spatially intelligent species, such as octopuses (Godfrey-Smith, 2017).

The relationship between what is explicitly in the genome, i.e. directly encoded in DNA, and the "long range" influence of the genome in an adult organism is complex and indirect. This is perhaps clearest in the case of human linguistic competences: only the human genome, among known species, has the ability to produce adult individuals communicating and understanding (giving and receiving information) in a rich human language. But the languages used for communication by adult humans vary enormously, in syntactic structures used, semantic contents expressed, communicative functions, and the modes of production (e.g. spoken languages, signed languages, written languages, typed languages (using keys on a computer keyboard), and the skin-contact language developed by Helen Keller's teacher Anne Sullivan for communication with the deaf and blind child (see `https://en.wikipedia.org/wiki/Helen_Keller`).

Such diversity in the relationships between what is in the genome and the long term effects of genome contents raises serious challenges for simple theories of what genes are, what they can do, and how they are related to their products. Compare the criticisms in (Godfrey-Smith, 2007).[1].

The *Meta-Configured genome* (MCG) theory, developed with biologist Jackie Chappell, attempts to show how this lack of specificity in the genome can illustrate both the great power of products of biological evolution and the diversity of mechanisms and sub-processes used in gene-expression. An introduction to the MCG idea (including a short video) can be found here: `http://www.cs.bham.ac.uk/research/projects/cogaff/movies/meta-config`. But most of the details are still unknown.

In humans, spatial-cognitive abilities concerned with perception and action are extended by additional (late developing) self-reflective mechanisms, used in diagnosing flaws in behaviours, repairing them, extending them, combining them, or teaching them to others.

Some non-human primates share aspects of these competences – partly illustrated by their ability to engage in various kinds of play with humans and among themselves (e.g. between parents and offspring) found in orangutans and gorillas, for example. Compare the complex relations between humans and some varieties of dogs (e.g. sheep-dogs).

Recent (unpublished) developments of the MCG theory suggest that in addition to the externally observable multi-stage changes in competences there are also *unobservable* multi-stage changes in competences used within developing individuals, e.g. multi-stage processes in chicken eggs and crocodile eggs producing increasingly complex internal structures and internal behavioural competences that repeatedly extend/enrich the processes of development used to produce the new chicks or baby crocodiles that eventually emerge from their eggs ready to perform quite complex actions (e.g. chicks pecking for food and following the hen) very soon after emerging from the egg.

This completely undermines currently fashionable theories that assume all complex intelligent behaviours must be products of extended processes of empirical learning by interacting with the environment in order to train neural nets. Such theories also fail to take account of the fact that

[1] Unpublished research by Francesca Bellazzi at Reading University is also relevant

some (proto-mathematical) spatial reasoning competences include abilities to recognize examples of impossibility and necessity, which, as Kant pointed out, cannot be based on empirical learning. Impossibility and necessity cannot even be expressed in standard neural net models that deal only with statistical evidence and derived probabilities.

These considerations open a window into a large, mostly unexplored, jungle of ideas, in which old philosophical problems are related to previously unnoticed aspects of biological evolution and development in a variety of species, including humans. The still incomplete theory being developed includes:

– complexity and diversity of evolved abilities to develop competences relating to external spatial structures and processes and many internal structures and processes: starting from competences of single-celled organisms, through species using increasingly complex chemically controlled biochemical construction processes during reproduction and early development, especially in more recently-evolved organisms such as vertebrates born or hatched with extremely complex physical bodies combined with very powerful, *extendable control mechanisms* with many layers of complexity, including mechanisms for internal behaviours such as production and growth of new body parts, development of mechanisms for digestion of food, tissue repair, waste disposal, immune responses, and many more.
  - *e.g.* processes in hatching eggs of chickens, alligators, etc., during which increasingly complex and varied body-parts are assembled in increasingly complex and varied relationships, before new individuals emerge from the shells,
  - based partly on multi-layered construction of new *construction mechanisms* within unhatched eggs,
  - including mechanisms for constructing *information-based control mechanisms* required for more complex developmental processes within eggs, at later stages,
  - especially in organisms born or hatched with significant pre-assembled cognitive competences, e.g. newly hatched chicks, ducklings, baby crocodiles, with spatial competences, and even some mammals (deer) that find their way to the mother's nipple and run with the herd soon after birth,

– and increasingly complex and diverse developmental processes across evolutionary time scales (compare insects and vertebrates),

– evolving increasingly complex *metaphysical creativity* of developmental processes,

– using increasingly complex and varied biochemical mechanisms in those developmental and evolutionary processes,

– far beyond the scope of "neural net"-based explanations of spatial intelligence (e.g. since neural nets cannot discover, or even represent, necessity or impossibility),

– with deep implications for neuroscience, philosophy of mathematics and philosophy of mind, including varieties of consciousness,

– and philosophical relevance of aspects of a wide variety of *scientific* research fields, including physics, biochemistry, developmental biology, immunology, sub-cellular neural mechanisms, neural abnormalities and their effects,

despite many remaining deep gaps in our current knowledge about such processes.

Notes:

– Some of these ideas were triggered by reading Erwin Schrödinger's ideas in *What is life?* (1944) regarding the importance of quantum mechanisms for reliable reproduction.

– *Compositionality* is normally thought of as a feature of human languages. However there is a more general concept that is applicable to many of the processes of evolution and development referred to above, as discussed in
`http://www.cs.bham.ac.uk/research/projects/cogaff/misc/compositionality.html`.

Illustrative videos of hatchlings, etc. will later be made available at

`https://www.cs.bham.ac.uk/research/projects/cogaff/movies/apa/`

Further notes

There is fragmentary evidence that Alan Turing was thinking about a project of this sort when he wrote his 1952 paper on chemistry-based morphogenesis, explaining formation of surface patterns on organisms, while his unstated long-term intention was much deeper and more important than explaining how visible patterns form. The label "Meta-Morphogenesis" was introduced to refer to that more ambitious project in (Sloman, 2013). Continued development of the project since then is reported in a growing collection of online documents referenced in `http://www.cs.bham.ac.uk/research/projects/cogaff/misc/meta-morphogenesis.html`, which include a theory of evolved construction-kits, including construction-kits created during processes of development of individual organisms in fertilized eggs, or seeds, and construction-kits for building new construction-kits.

There seems to be little or no recognition of these processes and their implications in current philosophy of mind, psychology, neuroscience and AI.

So theories developed in those fields are incapable of producing adequate explanations of a variety of phenomena, including spatial learning and reasoning in many species, ancient processes of mathematical discovery in geometry and topology, long before Euclid, and important aspects of human consciousness, including forms of proto-consciousness involved in multiple layers of increasingly complex information-based control mechanisms during development from fertilised eggs. Insofar as the key processes crucially involve both discrete and continuous change they cannot be fully replicated on digital computers, though they can be implemented in chemical processes for reasons pointed out in Schrödinger's 1944 Book (Schrödinger, 1944), though at that time he apparently did not notice their importance beyond explaining the possibility of reliable biological reproduction.

Background

Development of this "tangled network" of ideas began in 1958/9 when I switched from mathematics to philosophical research on the nature of mathematical discovery, defending Kant's view of mathematical knowledge as non-empirical, synthetic (not derived from definitions using logic), and concerned with necessary truths and necessary falsehoods (impossibilities). This led to a DPhil thesis (Oxford) in 1962. I later felt the claims and arguments could be improved, after encountering Artificial Intelligence, and learning to program, starting around 1970. A book, *The Computer Revolution in Philosophy*, resulted in 1978. It was later digitised and placed online at `http://www.cs.bham.ac.uk/research/projects/cogaff/crp/`, then repeatedly updated/extended with references to related AI topics and projects.

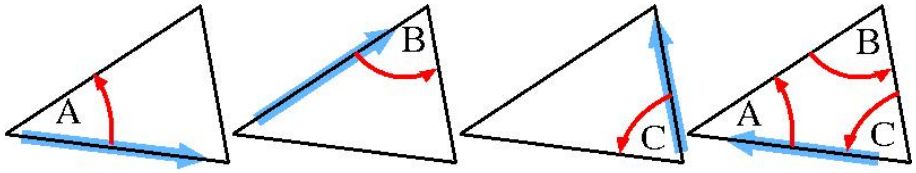
Models explaining how ancient mathematical brains made discoveries in geometry and topology centuries before Euclid, using forms of spatial reasoning processes in humans and other intelligent animals, need to explain how *impossibility* and *necessity* are represented and detected, especially *spatial/geometric* impossibility and necessity. This is not a general requirement for models of affective states and processes, e.g. desires, emotions, attitudes, etc. using information-processing architectures containing multiple interacting sub-systems, discussed in `http://www.cs.bham.ac.uk/research/projects/cogaff/misc/vm-functionalism.html`.

In contrast, pre-verbal human toddlers, illustrated in `http://www.cs.bham.ac.uk/research/projects/cogaff/misc/toddler-theorems.html`, nest-building in weaver-birds and crows, and spatial intelligence in squirrels, elephants, orangutans, dolphins, octopuses and many other species, require abilities to represent and reason about *necessity* and *impossibility*, closely related to ancient mathematical abilities. Probabilistic neural nets cannot represent or reason about these modalities.

My talk presents recently developed ideas about varieties of spatial monitoring and control not only in whole organisms but also in enormously complex and little understood chemical control and assembly processes in eggs that produce chickens, alligators and other animals, and in related construction processes and mechanisms in mammalian reproduction. I am sure that if Alan Turing had not died in 1954 he would by now have taken these ideas much further than I have – explaining his obscure distinction between mathematical intuition and mathematical ingenuity. `https://www.cs.bham.ac.uk/research/projects/cogaff/misc/turing-intuition.html`

I suspect he would have agreed that Mary Pardoe's (re-) discovery of the non-standard proof of the triangle sum theorem, presented below, was an example of use of mathematical intuition. She found that her students understood and remembered it more easily than the standard Euclidean proof that depends on properties of parallel lines.

Example of spatial, non-logical, mathematical reasoning



Mary Pardoe's proof of the triangle sum theorem.
(Not legal in Euclidean geometry: uses a rotating line)
https://www.cs.bham.ac.uk/research/projects/cogaff/misc/triangle-sum.html
See https://twitter.com/pardoemary/

Note for philosophy teachers

I suggest that, in view of what we now know about life, and the rate at which such knowledge is being extended, teaching philosophy of mind and philosophy of mathematics without teaching evolutionary and developmental biology is educationally seriously misguided.

References

Godfrey-Smith, P. (2007). Innateness and Genetic Information. In P. Carruthers, S. Laurence, & S. Stich (Eds.), *The Innate Mind Volume 3: Foundations and the Future* (pp. 55–105). OUP. (https://petergodfreysmith.com/PGS-InfoAndInnate.pdf)

Godfrey-Smith, P. (2017). *Other Minds: The Octopus and the Evolution of Intelligent Life*. William Collins.

Kant, I. (1781). *Critique of pure reason*. London: Macmillan. Retrieved from https://archive.org/details/immanuelkantscri032379mbp/page/n10/mode/2up (Translated (1929) by Norman Kemp Smith)

Piaget, J. (1952). *The Child's Conception of Number*. London: Routledge & Kegan Paul.

Schrödinger, E. (1944). *What is life?* Cambridge: CUP.

Sloman, A. (2013). Virtual machinery and evolution of mind (part 3) meta-morphogenesis: Evolution of information-processing machinery. In S. B. Cooper & J. van Leeuwen (Eds.), *Alan Turing - His Work and Impact* (p. 849-856). Amsterdam: Elsevier. (http://www.cs.bham.ac.uk/research/projects/cogaff/11.html#1106d)

Sloman, A. (2020). Varieties Of Evolved Forms Of Consciousness, Including Mathematical Consciousness. *Entropy*, *22(6:615)*. (https://doi.org/10.3390/e22060615)

The above is a small sample of references relevant to this talk.

Additional links to online papers under development (most also have pdf versions):

http://www.cs.bham.ac.uk/research/projects/cogaff/misc/meta-morphogenesis.html

http://www.cs.bham.ac.uk/research/projects/cogaff/misc/construction-kits.html

http://www.cs.bham.ac.uk/research/projects/cogaff/misc/toddler-theorems.html

http://www.cs.bham.ac.uk/research/projects/cogaff/misc/impossible.html

http://www.cs.bham.ac.uk/research/projects/cogaff/misc/compositionality.html

http://www.cs.bham.ac.uk/research/projects/cogaff/misc/schrodinger-life.html

http://www.cs.bham.ac.uk/research/projects/cogaff/misc/austen-info.html

http://www.cs.bham.ac.uk/research/projects/cogaff/misc/vm-functionalism.html

http://www.cs.bham.ac.uk/research/projects/cogaff/misc/architecture-based-motivation.html

http://www.cs.bham.ac.uk/research/projects/cogaff/misc/chewing-test.html