Comment

When are ants better than slime moulds?
Comment on “Does being multi-headed make you better at solving problems? A survey of Physarum-based models and computations” by C. Gao et al.

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Computer scientists and biologists have long been excited by the idea of using nature as inspiration for the design of optimisation algorithms. Starting with the ground-breaking advent of the ant colony optimisation algorithm (ACO), which was based on the collective behaviour of trail-laying ants, research into bioinspired optimisation methods has proliferated resulting in a zoo of algorithms with names like Chicken swarm optimisation, Grey Wolf Optimisation, Elephant Search Algorithm, Moth Flame optimisation and Artificial Algae Algorithm to name just a few (reviewed by Darwish [1]).

During the 1990’s, bio-inspiration was dominated by the ACO and its variants. Then, in 2000, a new model system came from an unlikely source: the then-obscure slime mould, *Physarum polycephalum*. Even to biologists, slime moulds like *P. polycephalum* are deeply bizarre organisms. Contrary to their misleading name, slime moulds are not fungi; they are giant single-celled amoebas lacking a brain, nervous system or organs [9]. Pieces cut from the main slime mould cell become fully functional individuals capable of the full range of behaviours. If those pieces are reunited at a later date, they easily merge to form a single entity. In 2000, the breathtakingly original work of Nakagaki [6,7] demonstrated that – despite lacking a brain – *Physarum polycephalum* was capable of finding the shortest path through a maze. Nakagaki’s [6] ground-breaking work captured the imagination of computer scientists leading to the proliferation of Physarum-inspired algorithms and models. 17 years later, Gao et al. [2] provide a comprehensive – and much needed – review that takes stock of the current field of *Physarum* models and computation, identifies major trends, and provides a framework which can be used to classify research achievements.

In this comment, I will focus on the question posed by Gao et al. [2] in the introduction: “are *Physarum*-based methods superior or are they simply the current fad?”.

*Physarum’s* popularity as a study organism is certainly on the rise; a cursory search on Web of Science for the term ‘*Physarum polycephalum*’ yields 2,845 publications, the majority of which are in cell and molecular biology/biochemistry, but with a significant number in ‘computer science’ and ‘multidisciplinary sciences’ (Web of Science, accessed 20 January 2019). The number of citations for *Physarum polycephalum* papers has been increasing steeply since 2005.

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1571-0645/© 2019 Elsevier B.V. All rights reserved.
While *Physarum*’s rapid rise in popularity across multiple disciplines is suggestive of a research fad, it remains to be seen whether the research community can sustain its interest in slime moulds. *Physarum*’s popularity as a model organism likely stems from its tractability. *Physarum* can be easily grown on agar; even moist paper towels will suffice. Unlike ants, which build transportation networks using invisible chemical ‘pheromones’, *Physarum*’s bright yellow tubules are easy to see and measure. Slime moulds operate on a tractable, experimental time frame, moving at ~5 cm per hour [3] at maximum allowing time lapse videos to easily capture network dynamics. Experiments can be completed within 24-72 hours which makes it relatively easy for researchers to test new ideas. In this respect, *Physarum* is a model taxon for bio-inspired design because it is possible for the people developing models (who may not be formally trained as biologists) to work directly with the organism being modelled.

*Physarum* does, however, suffer from some weaknesses as a model system. One of the strengths of studying social insects such as ants is that many of the actions leading to collective outcomes can be observed directly; this can simplify the modelling process. In *Physarum* it is difficult to even delineate what an ‘individual’ entity is, let alone track and measure that entities behaviour. Without a good grasp of individual behaviour, it is difficult to know whether or not models are accurately capturing the decision process that occurs within slime moulds.

Despite logistic limitations, Gao et al. [2] suggest that *Physarum*’s use of direct communication mechanisms may make it a better model than ants for dynamic problem solving (although see the following for examples of dynamic problem solving in live ant colonies Latty & Beekman [4]; Reid, Sumpter, & Beekman [8]). This is an interesting suggestion, and one that would benefit from follow-up experiments.

So are *Physarum* inspired optimisation methods truly superior to other bioinspired-methods? When is an ant colony better than a slime mould? Ideally, a clear understanding of the strengths and weaknesses of different types of bioinspired algorithms would allow researchers to select the model organisms most likely to yield useful insights for a particular application. However at present, direct head(s)-to-head(s) comparisons between bioinspired approaches have generally not been done. This gets at a deeper issue at the heart of bioinspired computing: under what circumstances, if any, do bioinspired techniques yield better solutions than conventional approaches? Unfortunately, these key questions remain unanswered.

Given the lack of direct comparisons between ant- and *Physarum*-inspired approaches, it may be premature to label *Physarum* as the superior model organism for bioinspired computing. Instead, *Physarum*’s meteoric rise should serve as a reminder that interesting and useful optimisation methods can lurk in unlikely places. Given the unimaginable diversity of life on Earth, which, at last count contains 1.5 million named species and an unknown number of undiscovered species (with estimates as high as 1 trillion [5], nature contains a rich toolbox of potentially useful optimisation methods. The challenge is for biologists and computer scientists to coordinate their efforts toward finding interesting new behaviours.

*Physarum*’s greatest contribution to bioinspired optimisation may thus be as an exemplar of cooperation between biologists and computer scientists. Biological experiments on *Physarum* have developed alongside computation approaches and collaborations between workers in different fields is frequent and collegial. The combination of experimental tractability, cooperation between life and physical scientists, and the slime moulds undeniable charisma (because who doesn’t love a slime mould?) has propelled an otherwise obscure and alien organism into the public and academic spotlight.

**References**


