Constructive Ignorance in the Physics of Life Network

Physics of Life research in the UK is transforming scientific insight and translational impact. Here I discuss its disruptive potential and barriers to interdisciplinary research through the lens of the activities of one of its pioneers, Tom McLeish.

Biophysics – biology-led questions requiring physics to resolve them – has pillars set in the foundations of 1950s physiology and structural biology[1]. Biological physics, on the other hand, was developed later and focuses on biology as a physics application. More recently, these two pursuits were brought together into the emerging field of the Physics of Life. Here, questions are not owned by life or physical scientists, but shared. This subtle distinction has transformative ramifications for how questions are contextualized, from ecosystems down to single molecules[2,3].

Earlier this year, Tom McLeish, friend and colleague, passed away, leaving a legacy touching soft matter and polymer physics, medieval science, religion, philosophy, poetry, art and music. Here, I reflect on his impact in the Physics of Life (PoL) and discuss the history and future directions of the UK's Physics of Life network (PoLNET), of which Tom was a founding member.

I first met Tom during PoLNET's 2012 inception. PoLNET made progress quickly through targeted workshops and summer schools funded from sparse resources to encourage physical and life scientists to talk to each other. But it was during Tom's tenure as PoLNET's chair from 2017 to 2022 that PoLNET transformed from a 'convivial talking-shop' into a powerful collective for interdisciplinary research. It was down to his singular efforts that a Strategic Priorities Fund was granted by the main UK government funder, UK Research and Innovation (UKRI), in 2018 to resource PoL research, with a budget two orders of magnitude greater than the network's own.

Disruptive potential

Rather than just creating bridges between disciplines — "decorating the boundaries" as Tom would say — interdisciplinarity has a potential to enrich and transform disciplines, leading into central questions of learning[4]. A motivation for the Strategic Priorities Fund was that PoL research had enormously disruptive potential. It would enable transformative research by contextualizing it in a different way with parity between life and physical sciences. Tom was instrumental in establishing a new structure for research consortia, insisting on 'co-PI' leadership from across the physics and biology interface. This aspect of co-creation significantly influenced the nature of research but also the way questions were configured.

Seeds of 'joint ownership' were sown early in the life of PoLNET during open discussions, and shoots grew in fledgling local PoL groups. I established one such group at the University of York in 2015, by bringing together a collective of approximately 50 researchers specialized in a range of topics reflecting the broad national demographic of interdisciplinary expertise. When Tom moved to the University in 2018 he joined the group's Friday afternoon seminar discussions and enriched them enormously.

Here, we created a safe environment where enthusiastic early career researchers (ECRs) – students, postdocs, untenured fellows – mingled with tenured academics in constructive ignorance. We fostered naïve fearlessness, to not be bamboozled by expertise, but ask what, on the surface, appeared to be stupid questions. However, these apparently "dumb questions" — as Tom would call them — posed from across the physics and biology interface sparked new ways of thinking about a problem. Tom saw the potential of this approach to re-imagine each question as a dialogue and endorsed it fully.

An interesting finding from these discussions was that this re-framing was not solely influenced by expertise. Language also played an important role in two contexts. The first context was translational: different terminology in physics and in biology for the same underlying phenomena. The revelation that seemingly distinct subject matters were actually the same research problem meant that rapid insights could be gained through approaches 'borrowed' from one discipline to the other. Tom was a great advocate for this, exemplified by his work on liquid droplet formation in living cells in which he 'rediscovered' Flory-Huggins theory[5], originally developed to model thermodynamics of polymer solutions.

The second context in which language was shown to be an important factor was epistemological — pertaining to the structure of knowledge. Physicists, it turned out, thought of problems in a different way to biologists, and vice versa. So, even if the objects of knowledge are the same, the nature of phenomena involving them might be differently perceived because the actual connections between these objects are discipline-specific. Recognizing that different approaches exist poses opportunities to develop new idea architectures that belong to neither physics nor biology. This is a characteristic of much of the PoL research across the UK funded by the Strategic Priorities Fund (links to the lists of the funded grant proposals from the first[6]and second[7] calls of this fund are given in the References).

Interdisciplinarity challenges

Recent reports highlight the power and tribulations of UK interdisciplinarity, concerning research councils[8], the research excellence framework (REF)[9], cultural challenges within UK academia[10], and housing PoL in physics departments[11]. A common observation is that interdisciplinarity taps into UK funder remits well but is hampered by organisational and administrative structures. Some of these barriers are beginning to erode through merging councils into a single UKRI umbrella, but many remain.

After Tom's passing, I took on the role of PoLNET's chair. Challenges of interdisciplinary funding and career sustainability were reflected in a straw poll I took at a recent PoL roadmap discussion[12]. This event is a legacy of Tom's impact in PoL — a unique meeting in which major UK stakeholders of PoL, biological physics and biophysics research came together. Making a rough estimate, 70% of participants identified as ECRs, 1/3 had core background in life and physical sciences each and the remaining 1/3 claimed equal expertise in both; when asked what they would most like to discuss, 'funding' and 'career' were the most prominent (Fig. 1).

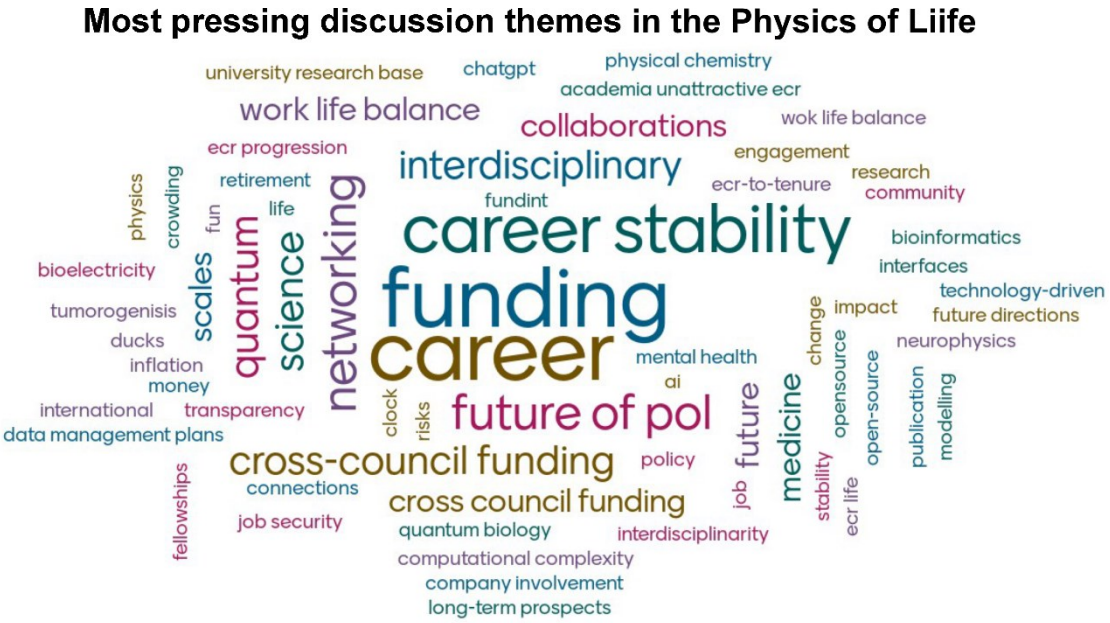

Figure 1 **Pressing discussion themes at the Physics of Life 2023 Conference** *Mentimeter.com poll taken during Physics of Life Roadmap discussion panel at PoL 2023 conference, Harrogate, UK, 29 March 2023 , involving ~200 respondents to questions concerning career stage, area of self-indentified research, and what they would most like to discuss.*

Finding that the bulk of participants were ECRs was no surprise, but the balance between life and physical science, and the presence of a significant population identifying equally with both, was. One of the challenges at PoLNET's inception was getting life and physical scientists in the same room at the same time. Now, thanks to PoLNET, this barrier is significantly diminished.

There were anecdotal suggestions that inappropriate reviewer expertise of PoL grants was still a challenge. However, this problem appeared less prevalent than during initial discussions a decade ago. A more pressing challenge was that grants were still often judged by monodisciplinary funding panels, making it potentially difficult for PoL proposals to compete with monodisciplinary bids. However, an important success of the PoL Strategic Priorities Fund process was the establishment of a cross-disciplinary panel. Making this the default across funding bodies could have major benefits.

A larger issue regarding how PoL grants are assessed is a perception that PoL reviewers are more conservative in rating their peers' research compared to monodisciplines. Do some biologists more harshly evaluate proposals of physicists, and vice versa? Is the PoL community 'immature' compared to disciplines like nuclear and quantum physics whose members score more favourably when reviewing peers? These speculations need to be further debrided through open community discussion. However, although there are aspects of getting one's house in order that are worth reflecting on for PoL, a more pressing aspect is how best to resource research, which requires discussion with those holding the purse strings.

Physics of Life roadmap

UK PoL research is at a turning point with more funding needing to be secured, exemplified by the submissions of grants to the most recent PoL Strategic Priorities Fund call: 171 outline bids submitted but resources sufficient to fund only nine. In having been privy to successful and

unsuccessful bids I sense in cases only marginal distinctions discriminating triumph from failure; the quality was there in abundance.

Although £33M sounds plenty, the UKRI contribution to PoL is equivalent to just 1% of its total budget for the financial years 2022-25. Given that the field spans the remits of multiple funding councils within UKRI and aims to resolve societal challenges through innovative and transformative research, is 1% enough?

An important factor for PoL's future is to nurture support from charities which sponsor interdisciplinarity, especially at the border between physics and biomedicine. At the time of writing, UKRI supports research that fits with five strategic priorities[13] – moving to a green future; building a secure and resilient world; creating opportunities and improving outcomes; securing better health, ageing and wellbeing; tackling infections.

If the PoL community works with UKRI to align with these goals this will surely favour increased resourcing. There are indicators of existing alignment in recently funded PoL themes: tissue morphogenesis, brain function, understanding super-bugs, innovations to capture carbon inspired by simple algae and more. Increasing scope for themed challenges in PoL research from multiple bodies across physical sciences, biology, biomedicine and the environment, will serve to diversify funding, making the field more resilient for when individual funders tighten their belts.

There are also funding lessons to learn from international partners. There are valuable recommendations worth musing over in the recent report put together by the Physics of Living Systems network at the US National Science Foundation, which provides an extensive discussion of the future challenges of the field[14]. It is also helpful to look at alternative localised hub models that structure interdisciplinary research into themed groups as seen in many collaborations between geographically close universities of the Netherlands, and in the >80 Max Planck institutes of Germany.

Increased engagement involving non-academic partners also presents opportunities for PoL. As Tom pointed out regarding soft-matter physics "[it] does exactly what it says on the tin… and very often it is in the tin…" – the implication being that it has real-world implications relevant to industries ranging from food production to shampoo design, which he recognized were desperate for scientists skilled in physical and life sciences. But it is crucial to also recognize the effort involved in negotiating these challenge-led projects that balance industry needs against basic science development.

UKRI facilitates Prosperity Partnerships and Industrial Cooperative Awards in Science & Technology (iCASE) PhD studentships to catalyze industrial engagement. However, there is persistent disparity between the few large multinationals that can invest in these initiatives versus the large number of small and medium-sized enterprises interested in these types of collaborations but lacking the necessary resources.

Although it is vital that research partnerships between industry and academia balance translation with discovery, the importance of curiosity, of asking dumb questions, should never be forgotten. The science successes in UK's COVID19 vaccination response illustrate this, since much of our readiness emerged following many years of curiosity-driven research.

One clear issue which a PoL roadmap must address is how to grow its pool of ECRs, and to ensure that we cultivate the community's diversity. This area was very close to Tom's heart and was a key point that he focused on when chairing the Royal Society's Education Committee. The traditional model of sponsoring young researchers via tenure track programmes and independent fellowships works for the gifted few; it is imperative that funders of excellence in interdisciplinarity continue to do so. But a challenge remains: these traditional routes can unintentionally exclude on the basis of gender, social status, age and geography, and simply do not cater well for many talented postdocs.

ECR mentorship is vital here, and PoLNET is playing an important role in coordinating this. One suggestion is to create more research officer positions: senior postdoctoral posts supporting multiple teams whilst still enabling a path to independence for postdocs. To enable this, PoLNET is working with UKRI to develop postdoc 'pump-priming' funds to better nurture the next generation of PoL researchers. Increased outreach into schools will also be invaluable. Currently in the UK schoolchildren tend to choose between the life and physical sciences very early, which has implications for gender diversity in physics when studied beyond school; this can be seen reflected in the UK Institute of Physics' diversity survey for 2019 which, although suggesting an increase in the proportion of female respondents from 2011, 2015 surveys, indicates that only 17% of its members overall identified as being female[15]. These statistics compare with those from the Royal Society of Biology for the period 2011-12 in which 61% of bioscience postgraduate students were women[16].

An essential action for growing the PoL community is to continue to support the underpinning activities of PoLNET itself – the network will likely play a pivotal role in securing that common vision and purpose for the field that will be enormously beneficial for the UK.

Reflections

I will miss Tom enormously, his intelligence, humor and kindness (Fig 2). He understood that researchers and decision-makers are human, often resorting to traditional temptations of monodisciplinary research. But what he also understood was never to give up on anybody, to listen to their needs and fears, to help reveal the power of research with non-traditional colleagues; having faith to take your hands off the reins for a while and just allow the horse to do the steering.

Figure 2 **Tom McLeish, FRS: 1 May 1962 - 27 February 2023.** *Ever a vibrant pedagogue of interdisciplinarity. Photo credit: Prof Giles Gasper (University of Durham).*

His passing leaves a void, but one being filled by the emergence of inspirational research in PoL, driven by the next generation of ECRs. I feel blessed to have known Tom, and to have played a small part with him in search of understanding through asking what appear to be dumb questions. All PoL research starts with that. For, as Tom knew very well, there actually really is no such thing as a dumb question.

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