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Editorial: Editor's challenge in interdisciplinary physics: what is interdisciplinary physics?

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Editorial on the Research Topic
Editor's challenge in interdisciplinary physics: what is interdisciplinary physics?

The question I had in mind when launching this Research Topic was where to draw the border between physics and its neighboring sciences in the rugged landscape that science constitutes. In the context of the Frontiers in Physics Interdisciplinary Physics Section, determining where the borders are defines the scope of the section.

I have earlier argued that physics has changed its character by shifting its focus from being defined by the type of problems it deals with to becoming defined by its approach to Nature [1]. I wrote this: "Physics has spilled over its boundaries set by the definition quoted, and we now have fields such as econophysics, sociophysics, biological physics, and geological physics. Common for these new fields of physics is that if they are to be defined based on the subjects that are studied, they would not belong to physics. What *does* make them part of physics is rather the way the subjects are studied. By regarding these new fields as belonging to physics, the dictionary definition of physics [*the study of matter, energy, and the interaction between them*] no longer holds. One [must] revise it. It makes sense to replace the old definition stating that physics is the study of certain quantities by one where physics is defined as a method to approach scientific problems."

Is such a description of physics compatible with seeing science as a landscape, where each point in the landscape is some scientific question and the different scientific fields such as chemistry, biology etc., are countries will well-defined borders? I would say no. In this picture, physics has become more of a "transnational organization" than a country. Perhaps – with a risk of pushing this picture way too far – one may think of the Catholic church that both is a transnational organization and having its own territory, the Vatican.

A definition as the one proposed for physics is only useful if it makes it possible to answer the question, is this physics or not. For this to be possible, we need to describe what is meant by "a method to approach scientific problems." As I wrote in 2014 [1], the physics approach may be characterized by it being *hierarchical*. By this I mean an approach that starts by posing more general questions and then proceed towards more specific questions. For example, answer the question "what is a metal" before answering the question "what is copper."

Physics is centered around experiments. That is, posing direct questions to Nature. The better designed an experiment is, the clearer will the answer be. Examples of such experiments are those of Ørsted, Ampère and Faraday in electromagnetism, conducted around 1820–1830. In 1861–1862 James Clerk Maxwell published his synthesis of these experiments expressed as four equations. These four equations account for essentially all of electromagnetism. The experiments offered glimpses of the nature of electromagnetism from different perspectives. Maxwell turned them into a complete description with power of prediction. The key word here is *synthesis*. The synthesis of the experiments on how liquids behave into the Navier-Stokes equations, presented by Navier in 1822 and Stokes in 1845, is another example of the same process.

Superficially, these two examples seem to go against the claim that physics is centered around a hierarchical approach to Nature. Are not the theories of Maxwell and Navier-Stokes more general than the preceding experiments? My answer is no. The experiments and the final synthesis are examples of general questions: what the nature of electricity is and what is the nature of flowing liquids. Only after such a synthesis could one invent the radio.

But do we not find the same type of hierarchical approach in other fields? For example, do we not need plate tectonics before understanding the Himalayas in geology? Plate tectonics is a more general concept than the Himalayas. And in biology, do we not need the Darwin theory of evolution before we can begin to understand the increasing pesticide resistance? The answers are yes, yes and yes. These are examples of the same hierarchical approach. So, is the conclusion that these are examples of physics even though they appear in geology and biology? No, nobody would accept this. And the conclusion must be that defining physics in this way is too superficial.

But, at the same time, physics *has* changed character and *is* invading its neighbors. We need a definition of physics that goes beyond "the study of matter, energy, and the interaction between them."

Perhaps the question of defining physics in a way that distinguishes it from other fields is an unnecessary question? Perhaps it should not even be posed? Another division is the distinction between basic and applied research. The book *Cycles of Invention and Discovery* [2] discusses at length the viewpoint first heralded by Vannevar Bush that such a division is harmful to science. It prevents progress by introducing artificial boundaries that impede collaboration. Is it the same here? Forget about the boundaries between different disciplines, collaborate across these artificial boundaries. Different disciplines are taught in different ways, with different emphasis on the different aspect of a given problem. Combine them and prosper scientifically!

In fact, what I just did was to argue for the importance of interdisciplinarity – and this means removing the artificial boundaries between disciplines.

So, my views have evolved in the 10 years since my 2014 paper [1]. In another 10 years, who knows what they will be.

This Research Topic contains four papers. Two of them provide examples of interdisciplinary research and two of them take a step back and attempt to put interdisciplinary physics in context. Here is a synopsis of each.

Galam's paper *Physicists, non-physical topics and interdisciplinarity* is a thoughtful discussion of what physics is today and in particular, the role of interdisciplinary physics. His definition of physics is "that which physicists do." This is fully in line with my thoughts expressed contortedly in the present editorial. Then he turns to interdisciplinary physic. He writes "Interdisciplinary physics should be a cabinet of curiosities including an incubator." The idea is this: Interdisciplinary physics concerns physics outside its traditional pastures. Occasionally, a new pasture outside is found for physicists in the context of interdisciplinary physics that ends up being a new subfield of physics. Two concrete examples: sociophysics and econophysics – today both well-established fields. In my opinion, this is a new and very fruitful way regarding interdisciplinary physics. As a very early worker in sociophysics, he recalls the struggles for acceptance of touching such problems in the context of physics. Young physicists will not know how tough it was. I can recall the struggle which unfolded in getting computational physics accepted as a proper sub field of physics. But the struggle that Galam recalls was tougher. Galam has provided the Interdisciplinary Physics Section of Frontiers in Physics with a clear vision: *To be an incubator for new subfields of physics.*

Success of social inequality measures in predicting critical or failure points in some models of physical systems by Ghosh et al. is a review article on how statistical physics may be applied to quantitative studies of social inequality. They map the measures of inequality developed in economics, the Gini and Kolkata indices, on to models developed within statistical physics, such as percolation and the fiber bundle model – the first originally developed to understand of fluid percolation (such as in coffee machines) and the second to understand fracture processes in materials. On the surface, it looks like there is no overlap between coffee percolators, cracks and social inequality. But – and this is how physics works – when all the peculiarities of each problem are stripped away, what remains is a common framework.

The third paper in this Research Topic, *Scaling behavior of the Hirsch index for failure avalanches, percolation clusters, and paper citations* by Ghosh et al. is a research paper addressing the most used index to measure quantitatively the quality of scientific authorships, the Hirsch index, which balances the number of papers published by a given author by the number of citations received. This is an important index as it is used extensively in hirings and promotions. The authors demonstrate the power of physics by using percolation theory and the fiber bundle model to understand how the Hirsch index distribution within groups of scientific authors scales with the size of the groups. Again, a great example of interdisciplinary research where similarities between processes that seem completely unrelated are accentuated and utilized.

Profile and challenges of interdisciplinary physics by addresses the problem of defining physics and in particular interdisciplinary physics. He points to the remark made by Parisi [3] that the term prediction has acquired a weaker meaning over time, and this has led to a broadening of the scope of physics. In other words, it has led to what we now call interdisciplinary physics. He discusses the concept of "reinterpretation," which is precisely the two papers by Gosh et al. are focused upon. Physics provides the *core concepts*, which are then interpreted in a new context that is outside physics classically defined. The discussion that Mantegna presents in the Introduction, is important. He states that the interdisciplinary physicists "know what they are not, but they miss the positive aspects and values of their identity." The way I interpret this is that they fall between chairs. We see this in practice when applying for research grants: you wish to apply techniques from field A in field B, which is a cross-disciplinary approach. There are two referees, one from field A and one from field B. The one from field A does not find field B interesting and the referee from field B does understand the utility of the field A tools. Result: it is much more difficult to succeed in cross- and interdisciplinary physics than otherwise in physics.

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