

OPINION

Physics in Crisis

Sidney Nagel

Physics is in crisis. We have lost our ideals and focus as a unified field.

The reasons for this loss can be traced to recent history as well as to pressures currently felt within the physics community. Particle physics used to be the dominant area and had pride-of-place in our discipline. It was “basic” and “fundamental.” It was exciting, with many great discoveries taking place and with a unified picture of the interactions emerging. Physicists were convinced that the best science was reductionist and that all other sciences, at least in principle, could eventually be predicated on, if not reduced to, physical laws. Even though, in practice, it would be impossible to accomplish such a vast reduction, there was comfort and pride in believing that our science was fundamental. Particle physics served as a culmination of that viewpoint: Other subdisciplines of physics were often seen as studying phenomena that merely originated from the relentless working-out of the laws to be discovered in the realm of high energy. As such, those other areas were relegated to a lower, secondary status. The goal of physics was to find the basic underlying laws of nature, and the most basic ones were those governing the elementary particles.

These attitudes have slowly been eroded. This is in part due to the fact that high-energy particle physics is no longer so healthy—particularly within the US since the demise of the Superconducting Super Collider. Great discoveries and advances are less frequent. Without the preeminent role of particle physics, it has become less accepted what the ultimate goal of physics should be. Although there is great excitement in many different areas, no other group has risen up and taken the lead in defining our mission.

What is our overall objective as physicists? Do we know anymore? Whereas previously, understanding

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between fields was less important because of the dominance of a single viewpoint, now, with the decline of that position’s most visible exemplar, the splits between disciplines inside physics have taken on greater consequence, making better communication essential for restoring our sense of community.

Why are there splits within our field? First, there is a noted lack of sympathy between subdisciplines. There is a long history, which is better forgotten, that documents the

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uneasy relationship between particle physics and other areas such as condensed matter. This establishment of a pecking order is not unique to physics and is perhaps a common trait in many, if not all, academic disciplines. More discouraging is that, despite our best intentions and frequent objections to the contrary, we do not really appreciate what is done in other areas. I would venture that a colloquium talk with the words “standard model” in its title would not be immediately engaging to a condensed-matter physicist, nor would one with the words “high-temperature superconductivity” be attractive to a community of particle physicists (nor, for that matter, to a group of soft-condensed-matter physicists). I could give many other examples from all different areas in physics. Such division is clearly not good but I think it is a shocking and unfortunate fact. We are, it seems, very parochial.

A second split is the inevitable conflict between big and small science. Big physics has gotten much bigger, with collaborations ballooning in size, whereas small physics, if possible, has

gotten even smaller. Not only are some experiments done with a minimum of personnel, but they also use a minimum of sophisticated equipment. This leads to the troubling question: Why should a condensed-matter physicist pronounce on the hiring of a high-energy particle physicist and vice-versa? We can, of course, listen to our colleagues and either choose to believe their opinions or not, but we could do the same for our colleagues in, say, the English department. What do we share as physicists that makes our opinions important to our departmental colleagues?

A third split that emerges is that between basic and applied. We are often caught arguing which is “better,” as if that had a meaningful answer; we then straddle the fence and proclaim that our research has aspects of both.

Finally, I come to the split between the study of emergent phenomena and reductive science and to the ongoing debate about which of the two is more useful or interesting. Many of us no longer blindly buy into the idea that reductionism is superior to other science. Using a metaphor that I learned from Leo Kadanoff, we can ask whether nature is an apple or an onion. That is, does nature have a core that is fundamentally different from the outer region and that contains the seeds of truth (the reductionist viewpoint); or is it an onion in which each layer is only loosely attached to the one beneath it? So, in order to study geology, condensed matter physics, or biology, does one really need to know the standard model? Does it even help? Of course not. Likewise, we can ask whether the standard model is so fundamental that we need it before we can build a strong scientific structure. I would suggest that we can even turn that question (and with it, the reductionist agenda) around and argue that one cannot study particle physics without knowing about more macroscopic physics. In that point of view, we would say that our knowledge about the more microscopic world is based on our understanding of the macroscopic one. Science, as a whole,

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provides one interrelated, mutually consistent description.

There are other trends aggravating these tensions in the community. In recent years, at least in condensed matter science, there has been an emphasis on interdisciplinary research. This diminishes our sense of a common physics mission. However, it is difficult to engage in interdisciplinary research without the solid foundation of a discipline from which to start. Because we have only finite time, energy, and attention to lavish on neighboring fields, interdisciplinary research can lead to an even further decrease in the communal activity within physics itself.

At the same time there has been tremendous excitement in other fields such as biology and computer science. Those fields have now outstripped physics in terms of excitement in the public eye, and we have lost students to those disciplines. This loss makes us uneasy and less confident of the value of our own research areas. While competition for funding has always been stressful, we feel overlooked as more funds are delivered elsewhere (such as to the health disciplines). In response, we often make

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exaggerated claims for our field that only infuriate our physics colleagues. In particular, credit is sometimes taken by one field of physics for the accomplishments of another. In our self-evaluation, we don't know whether to be practically useful to society or to answer the "big," intellectually satisfying questions that may have no obvious applications. Finally, I believe that none of this is helped by the growing split between theory and experiment in all areas of physics.

If there are splits within our discipline, we must then rediscover what different areas have in common. Is there a common approach to problems or a common type of question that we, as physicists, tend to ask? I can think of some possible, but not wholly satisfactory, answers to this query: For example, we might say

that we study universal features of how matter and energy can be organized. Although vague, this description nevertheless captures at least some of the strands interweaving our subject.

Likewise, we must articulate more clearly, so that we can all understand, what are the big questions we still need to answer that will launch new fields of research rather than close off old ones. I can only give an illustration from my own area but I hope that we can get examples from all our work. Starting the exercise, I ask, How do we begin to think about systems far from equilibrium? From one point of view, all of life can be considered as simply an organized struggle to delay our descent into bland equilibrium. If we were in equilibrium, we would not only be dead—we would be homogeneous! A question such as this is clearly central, open-ended, and will not be answered in a few years. I urge us all to contribute to this dialogue and suggest our own set of grand questions. In doing so we can provide a basis for the argument that physics is as exciting and relevant today as at any point in the past.

Clearly, we have not been very good