

OPINION

Particle Physics and Our Everyday World

Pablo Jensen

In a venerable physics journal, Robert Cahn has claimed¹ that his field of inquiry, particle physics, is essential to the understanding of our everyday world. He says that “particle physicists construct accelerators kilometers in circumference and detectors the size of basketball pavilions not ultimately to find the *t* quark or the Higgs boson, but because that is the *only* way to learn why our everyday world is the way it is” (emphasis added). In short, Cahn justifies particle physics and the inherent reductionist approach by employing a constructivist hypothesis: “Given the masses of the quarks and leptons, and nine other closely related quantities, [the current theory of particle interaction] can account, in principle, for all the phenomena in our daily lives.” This reductionist vision seems to be shared by many other particle physicists, as exemplified by Chris Quigg’s article on the discovery of the top quark (PHYSICS TODAY, May 1997, page 20). Quigg quotes Cahn’s article to support the idea that “the top quark helps shape the character of the everyday world” and that “the microworld does determine the world of quotidian experience.”

In this brief reply, I would like to reopen a debate in the physics community by arguing that these ideas are wrong, that even if we knew all the “fundamental” laws, we could not say anything useful about our everyday world. Our everyday world is irreducibly macroscopic, and we need macroscopic concepts to understand it. Contrary to the pretensions of particle physicists, we must recognize that science is organized in rather decoupled layers, each one with its own elementary entities or concepts, which generally are not simply derived from those of the lower level but constructed in creative efforts. This vision implies that particle physics is practically irrelevant to understanding our everyday world.

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It is true, of course, that if one could examine universes in which the values of the Standard Model’s 18 parameters were different, most and perhaps almost all of those universes would be unrecognizable to us. Trying to predict how the world would differ, as Cahn does for a number of examples, is an interesting exercise, but it is naive to imagine that untestable speculations of this sort can tell us much of relevance to understanding the macroscopic realm around us. After all, if we learned tomorrow that previous results and analysis had overlooked certain systematic errors, and the *t* quark mass is near 195 GeV and not 175 GeV, it is particle physics that would have to adjust to remain in agreement with the rest of physics, and not vice versa.

Symmetries

Before turning to the heart of the matter—the need for macroscopic concepts—I would like to discuss two examples of unexpected features that appear when one considers systems containing many particles; what Philip Anderson has summarized by “More is different.”²

First, the idea of “broken symmetry” shows how the symmetry of the fundamental laws is broken (not violated, just broken in practice) as soon as you study systems containing a few particles. Quantum mechanics predicts that the ammonia molecule has no dipole moment since the stationary state of this molecule is a superposition of two states having opposite dipoles. However, there is an energy barrier between these states, which can “freeze” the molecule in one of the degenerate states. Therefore, any measurement of the dipole moment of the molecule made at short timescales will give a nonzero value, in apparent contradiction to quantum mechanics. Taking larger molecules with handedness, or chirality, (for example, a sugar or any biological molecule) evidently increases the effect, and these molecules do not pass from one chirality state to another at any measurable rate. Therefore, for all practical purposes, large molecules do not show the

symmetry expected from the fundamental laws—in this case, quantum mechanics.

Second, in the study of phase transitions, physicists have found “universal” exponents, which depend on the dimensionality of the space and some symmetries, but not on the details of the microscopic interactions. For example, the liquid–gas transitions for different fluids such as O₂, CO and Ne can all be characterized by the same critical exponent. The exponents reveal something about the collective behavior of the system and are not determined by the microscopic interactions.

Emergence

The point is that each level of complexity has to be studied with its own instruments, and requires the invention of new concepts adapted to describe and understand its behavior.³ In principle, if God lent us his computers, a divine computer simulation might give us all the coordinates of the atoms during the mechanical deformation of a solid. However, such a huge amount of data would be completely useless if we did not have the relevant concepts (such as dislocations) to understand what was going on. Trying to use particle physics to understand our everyday world is like trying to understand how my computer can print this text by studying the movement of the electrons inside the chips, without paying much attention to the circuit organization, the hardware and the software! Intermediate concepts such as entropy, dissipative structures, cells, genes and so on cannot be simply “deduced” from the fundamental laws: they are said to be “emergent” because they arise at high levels of complexity and have to be invented at those levels to deal with specific situations. I claim that these emergent concepts are as real and as fundamental as the concepts and particles introduced by particle physicists.

Even outside science, the idea of emergent concepts is useful. For example, chess masters do not see the chessboard as beginners: they have developed clever “mesoscopic” analysis

patterns that allow them to understand what is going on and play much better.⁴ Similarly, single notes do not allow us to fully understand music: We need to also know about higher structural concepts such as chords and harmony. Finally, everyone would recognize that it is not enough to know all the letters of the alphabet to write a book. In this case one mesoscopic concept is the idea of words, which are necessary to communicate with people and carry meanings not carried by any letter of the alphabet. To say that everything is "contained" in the 26 or so characters of the alphabet can lead only to amusing intellectual fictions.⁵

Autonomous layers

It is interesting to note that recent developments in physics such as renormalization equations and effective field theories have strengthened the vision of science as an array of autonomous layers, each one with its own fundamental entities. (See Silvan Schweber's article, "Physics, Community and the Crisis in Physical Theory," in *PHYSICS TODAY*, November 1993, page 34.) A simple example of the physical meaning of these ideas can be drawn from everyday experience with a liquid and from considering how one explains the liquid's behavior. Is knowledge of the atomic structure of matter important in practice? The answer is no, and people have invented macroscopic concepts such as viscosity to understand the behavior of a fluid in many situations. Schweber summarized this point clearly in his article:

For a many-body system one can, by integrating out the short wavelength, high-frequency modes (which are associated with the atomic and molecular constitution), arrive at a hydrodynamical description that is valid for a large class of fluids, and which is insensitive to the details of the atomic composition of the fluid. The particulars of the short-wave (atomic) physics are amalgamated into parameters that appear in the hydrodynamic description. Those parameters, such as density and viscosity, encapsulate the ignorance of the short-distance behavior. The physics at atomic lengths—and *a fortiori* high-energy physics—has become decoupled.

In the same way,

Electrons and nuclei are the elementary particles of condensed matter physics, and the relevant features of the internal constitution of the nu-

cleus [are] embodied in the (empirically determined) parameters stating its spin, magnetic moment . . . and so on.

The point is that further research into the high-energy side may clarify why these parameters take these values but will not change the empirical values. These advances in renormalization theory render quite rigorous a remark made long ago by Anderson: "The more the elementary particle physicists tell us about the nature of the fundamental laws, the less relevance they seem to have to the very real problems of the rest of science, much less to the rest of society."²

Quarks and life

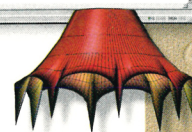
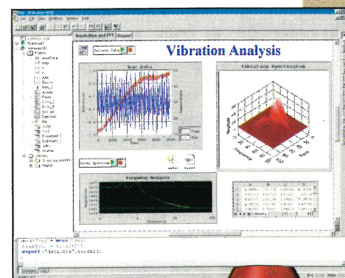
Let me conclude with some provocative remarks. It could be argued that, even if particle physics is not directly relevant to the understanding of our everyday world, it is at least a valuable source of knowledge of the world. We can agree on this: Breaking matter with higher and higher energies will give you more and more "fundamental" particles. However, the story of physics tends to show that there is no theory of everything waiting for us at high energies, and that it is more likely that this increasingly expensive race will never end, just as if we were trying to find the highest integer. We physicists should recognize that a significant part of our everyday world—the living world—is far beyond the realm of physics, and (some) particle physicists should get out of their accelerator labs and notice that their findings are primarily relevant inside their own professional network, as argued by Bruno Latour.⁶ By all means, let us each study our chosen "layer" of reality, whether it involves quarks or convective cells. But let us also remember that each layer is just one part of the greater whole. Accounting for all the phenomena in our daily lives *in principle* is entirely different from accounting for them in actuality.

Dedicated to "Clodi" Benski, my physics mentor.

References

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5. See, for example, the short story entitled, "The Library of Babel," in J. L. Borges, *Ficciones*, Grove, New York (1962).
6. B. Latour, *Science in Action*, Harvard U. P., Cambridge, Mass. (1988).

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