What's Wrong with These Questions?

N. David Mermin

On 15 August 2000, *The New York Times*, celebrating the new century, published a list of 10 questions that they characterized as ones physicists would like to ask their colleagues in the year 2100 if they awoke from a hundred-year sleep.

1. Are there reasons why the fundamental dimensionless parameters have the values they do?
2. What role did quantum gravity play in the Big Bang?
3. What is the lifetime of the proton?
4. Is supersymmetry a broken symmetry of nature?
5. Why is spacetime apparently four-dimensional?
6. What is the value of the cosmological constant, and is it really constant?
7. Does M-theory describe nature?
8. What happens to information that falls into a black hole?
9. Why is gravity so weak?
10. Can we quantitatively understand quark and gluon confinement?

You will not be surprised to learn that the questions were assembled at a party celebrating the conclusion of a conference on superstring theory. The *Times*, however, characterized them as "Physics Questions to Ponder," leaving me to ponder why they were so different in character from what I would be most eager to learn from my professional descendants at the end of a hundred-year nap.

The *Times* inspired me to put together my own list of the questions I'd put to a colleague in 2100. The criteria for inclusion on my list are (a) that I would love to know the answer, (b) that the questions should be likely to make sense to scientists in 2100 and not just to historians of science, and (c) that the questions should have a reasonable chance of not eliciting titters at my early 21st century naivete. Probably you'll find my list just as parochial as I found the string theorists' list. But here it is:

1. What are the names of the major branches of science? What are the names of the major branches of physics, if physics is still an identifiable branch? Please characterize their scope in simple early 21st-century terms, if you can, or try to give me some sense of why my ignorance makes this impossible.

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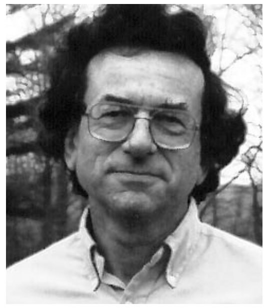

I can't imagine that the landscape will look familiar in 100 years. Already, for example—and this is bad news for physics—chemistry seems to be trying to become a branch of biology, as witnessed by the recent name changes of the departments at Harvard and Cornell, from chemistry to chemistry and chemical biology. Physics, on the other hand, seems bent on absorbing biophysics, defined in the broadest possible sense. Looking backward rather than ahead, what would a physicist from 1900 have made of the term "computer science," not to mention "information science"? You might complain that the real content of this question is "tell me everything of interest," but all I'd really like to find out here is what unfamiliar names are going to be there, and what familiar names are going to be missing.

2. Please show me a widely used, widely affordable device that will astonish me in as many different ways as a laptop computer would have astonished a physicist in 1900. At least some of the purposes served by this device should be as comprehensible to me as the uses of a laptop computer would have been to a late 19th-century physicist.

When you think about it, the number of ways in which a laptop would have amazed in 1900 is itself amazing. Forget about its primary functions. What about the material its case is made of, its cost as a fraction of mean annual income, the source of its power, its ability to imitate a symphony orchestra, its ability to show glowing pictures that move? Nobody imagined it in 1900. Nobody today can imagine what extraordinary objects will be found in the households (assuming there still are households) or pockets (assuming there still are pockets) of 2100.

3. Are fundamental theories still based on superpositions of states that evolve unitarily, or have the basic principles of quantum mechanics been replaced? If quantum mechanics has survived, have people reached a consensus on the solution to the interpretive problems, or have they simply ceased to view them as problems needing a solution? If quantum mechanics has not survived, has the theory that replaced it clarified these puzzles, or do people find it equally or even more mysterious?

I worry that this question might elicit polite bewilderment. But an appropriate time scale for the survival of quantum mechanics is set by the fact that its basic conceptual machinery has suffered no alterations for three quarters of a century. Even quantum field theory has as its most important application the calculation of cross sections, which exploits the same old unitarity of time evolution—the superposition principle—and the same old Born rule for extracting probabilities from states. So the persistence of the same formalism for another hundred years seems at least plausible.

If the theory is indeed still with us in essentially the same form in 2100, will there still be serious people, as there are today, who feel that in some fundamental sense we don't know what we're talking about? Or will the early 21st-century people who believed there ought to be a better way to understand the theory (if not the world itself) be assigned to the same dustbin of history as the early 20th-century ether theorists?

4. Have intelligent signals of extraterrestrial origin been detected?

I hope somebody keeps on looking. And I hope, if the answer is still no, that our descendants don't regard the search as silly.

5. Do time and space still play the fundamental roles they did in early 21st-century physics, or have they been replaced by more coherent, less *ambiguous concepts?*

How can people talk about spacetime turning into a foam at the Planck scale when we barely manage to define space and time at the atomic scale? Time, for example, is nothing more than an extremely convenient and compact way to characterize the correlations between objects we can use as clocks, and clocks tend to be macroscopic. To be sure, we can generate frequencies from atoms and correlate them with macroscopic clocks, but the shorter the length scale, the more it looks like you're talking about energies divided by Planck's constant. The connections with clocks become increasingly indirect. There seems to me to be a considerable danger here of imposing on an utterly alien realm a useful bookkeeping device we've merely invented for our own macroscopic convenience.

Time and space will still be with us in 2100, but I'm not so sure they'll be in evidence at the foundations of the scientific description of nature, whatever that discipline happens to be called.

6. Tell me about a collective state of matter, unimagined in the year 2000, that is as remarkable as, for example, superconductivity, superfluidity, or the fractionally quantized Hall effect seemed to be at the end of the 20th century.

Who could have imagined such phenomena in 1900? Surely the extraordinary capacity of bulk matter to behave in ways that transcend anything one could possibly have guessed from studying its constituents, will produce many comparably unimaginable things in the next 100 years.

7. Are room-temperature superconductors an important part of your technology?

This question might appear temporally provincial from the perspective of 2100, the recent flurry of interest in high-temperature superconductors being only 15 years old. But I am reassured by the fact that the broader quest has been with us now for almost a century, so it might not be presumptuous to guess that it could still be relevant in another hundred years. I'll take my chances that the question will not elicit giggles.

One could ask a similar question for similar reasons about controlled nuclear fusion, even though that quest has only been with us for about fifty years.

8. Has any progress been made in understanding the nature of conscious experience or how the mind affects the body, and does quantum mechanics or its successor play a fundamental role in that understanding?

There are those who say consciousness is a nonproblem because the question doesn't make any sense, and those who say it is a nonproblem because the answer is obvious. Physicists further divide into those who say quantum mechanics clearly does or clearly does not have anything to do with it. The problem of consciousness, of course, has been around for many centuries. But the growing sense, at least among physicists, that science has something to say about it does not seem to me transparently absurd, even though no two scientists can currently agree on what that something might be. The titter risk here is substantial, but I'll take my chances. I'd love to know whether the question will be viewed as vexing, as silly, or as substantially answered by 2100.

9. Did quarks turn out to be elementary or composite? If composite, did the candidates for their constituents turn out to be elementary or composite? Or do you have a better way of looking at these phenomena? What, indeed, is the lifetime of the nucleus of the hydrogen atom?

If string theory is already a better way of looking at these phenomena, the question may be partly answered. Maybe a better way to phrase it is this: What energy scales have you been able to reach, and have you observed new structure all along the way, or have things finally started to simplify, as people once innocently expected that they would?

10. Has anybody built a quantum computer that can factor a thousand-bit integer? What else is it used for? Do most homes have one?

This is the most rash of my questions, since the whole subject of quantum computation is so new that it all may well have evaporated by 2010. The question would then make sense in 2100 only to specialists in the history of science. But I like to think that so beautiful a gedanken technology will capture enough imaginations to give the quest for its realization sufficient impetus that—who knows—it might even succeed despite all current indications to the contrary. I'm hoping my intellectual descendants in 2100 will at least know what it is I'm talking about. If so, this will probably mean they've succeeded.

But I wouldn't bet my great-great-great-grandchildren's college tuition money on it. Assuming there still is money. Assuming colleges still charge tuition. Assuming there still are colleges. ■