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Is the Frontier Really Endless?

IN THIS ISSUE, THE NEWS TEAM AT *SCIENCE* NAMES ITS ANNUAL BREAKTHROUGH OF THE YEAR (see p. 1604). This year the honor goes to the first quantum machine—a microscopic cantilever ingeniously lowered to its lowest possible energy, the quantum ground state. The result may lead to ultrasensitive force detectors and to ways of controlling an object's mechanical vibrations as deftly as we now control electricity and light. It also heralds further investigations of one of the great mysteries of physics: the chasm separating the world of familiar objects from the bizarre realm of quantum mechanics.

There were other remarkable achievements this year, including the first cell with a synthetic genome and the deciphering of much of the genome sequence of our close, long-extinct relative, the Neandertal. And at long last, in the fight against AIDS, a new microbicidal gel that reduces a woman's risk of being infected with HIV.

This issue also adds something new: a look back over the past 10 years, highlighting 10 great scientific "insights of the decade" (see p. 1612). As emphasized, most of the insights have relied on the continued development of ever more powerful methods for investigating the world. Aided by new tools for peering out into space and for analyzing the molecules from which humans are made, among many others, the pace of scientific discovery is constantly accelerating. But most amazingly, it seems that whenever science increases our comprehension of the world, great new mysteries arise that need to be deciphered; from "dark energy" to the "dark genome" in the past decade alone. Moreover, discoveries in one domain can create new possibilities for breakthroughs in another. Thus, the discovery of water on Mars opens up the exciting possibility of discovering a form of primitive life on that planet, which may produce a better understanding of our own origins.

The question arises whether there will always be surprises, or if someday, perhaps thousands of years from now, there will be nothing left to discover. Can we ever expect to reach a complete understanding—an end of humanity's quest to understand the world through science?

Consider, for example, the grand challenge of deciphering how a multitude of cells cooperate with each other to form the human body. A cell is the fundamental unit of life, just as an atom is the fundamental unit of matter, and we have attained a highly sophisticated, but far from complete, understanding of its mechanisms. Loosely speaking, a cell is a collection of catalysts that, acting as a group, cause a complicated series of chemical reactions that end up duplicating all of the catalysts in the set. These are then divided into two sets, and the process starts over again with each daughter set.

But despite gaining an increasingly detailed understanding of the chemistry that underlies fundamental processes such as cell division, there are huge swathes of biology that puzzle us. The simplest cell known, a bacterium, contains about 500 types of catalysts in its set; the set in human cells is much more complex, with about 50 times the number of different types. In the year 2000, we thought that this added complexity was enough to allow the 100,000 billion human cells produced from a single fertilized egg cell to form the cell collaborative that we call a human being. Today we recognize that there are many more players in human cells, and that, amazingly, a total of about two-thirds of our essential genetic information—our "dark genome"—is needed for processes whose nature mostly remains a mystery.

Was Vannevar Bush right in 1945 when he described science as the "endless frontier"? Can we assume that if we solve the mysteries of the dark genome, new puzzles will arise? One can certainly hope so, because life would lose much of its grandeur and joy if we ever reached the finish line, with no further frontiers to challenge us.

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