EDITORIAL

Revolutionary technologies

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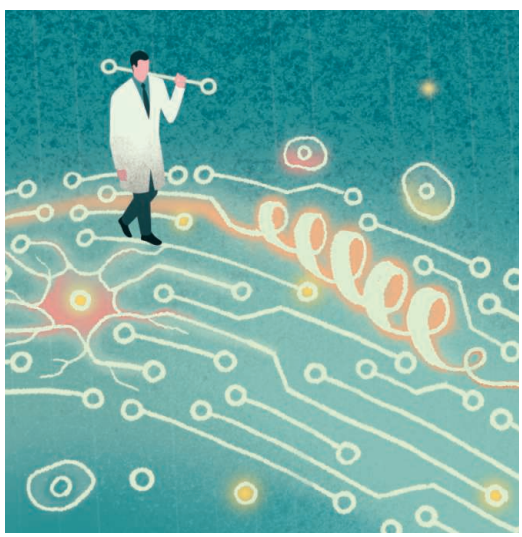
In this issue of *Science*, we present reviews of four technologies whose power and rapid growth across biological research communities make them revolutionary (see page 864). New technology is one of the most powerful drivers of scientific progress. For example, the earliest microscopes magnified images only 50-fold at most. When the Dutch fabric merchant and amateur scientist Antonie van Leeuwenhoek developed microscopes with more than 200-fold magnifications (likely to examine cloth), he used them to study many items, including pond water and plaque from teeth. His observations of "animalcules" led to fundamental discoveries in microbiology and cell biology, and spurred the elaboration of improved microscopes. Today, various light microscopes remain prime tools in modern biology. This example embodies two characteristics of a revolutionary technology: a capability for addressing questions better than extant technologies, and the possibility of being utilized and adapted by many other investigators.



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The discovery of x-rays in 1895 ushered in a multifaceted revolution in imaging. As scientists sought to understand the nature of these electromagnetic waves, they realized that they were diffracted by crystals, establishing that the wavelengths of x-rays were comparable to the separation between atoms in crystals. In 1913, William Henry Bragg and his son William Lawrence Bragg found that diffraction patterns could be interpreted to reveal the arrangement of atoms in a crystal. The Braggs determined the structures of many simple substances, including table salt and diamond. Others began using similar techniques to reveal more complex structures of inorganic and organic compounds. In the late 1950s, these methods were extended to determine the structure of proteins, and eventually to larger proteins and protein complexes. Thousands of structures are now reported each year and are foundational to our understanding of biochemistry and cell biology. Technical innovations, improved commercial and shared-facility instrumentation, and powerful software continue to drive the x-ray crystallography revolution.

As the field of recombinant DNA technology was evolving, a revolutionary technique in the form of the polymerase chain reaction (PCR) was developed by Kary Mullis (from 1983 to 1985) at the biotechnology company Cetus. PCR allows tremendous amplification of specific DNA sequences. It had an almost immediate revolutionary impact on many fields, including gene cloning and DNA analysis, and forms the foundation of many methods in modern molecular biology. PCR depends on several underlying technologies, including the chemical synthesis of short sequences of DNA and the availability of appropriate enzymes, but also machines for programmable temperature cycling. The method was invented shortly before I was setting up my first independent laboratory. Cetus had partnered with one company to sell PCR machines, although other devices with similar capabilities were available. I remember calling one of the other companies and asking if its machine would work for PCR. Concerned about patent issues, the sales representative said, "I can't say, but no one has said that it didn't work for their particular application!" My lab joined the PCR revolution.

The reviews in this issue of *Science* focus on two imaging methods that are extending and complementing the powers of traditional light microscopy and x-ray crystallography, and two methods for manipulating DNA to drive a range of discoveries and potentially powerful applications. Such technologies can help to resolve long-standing questions and can open up new vistas, revealing new phenomena and allowing the formulation of questions previously unimagined.

–Jeremy Berg

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