About Hardware

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There seems to be a consensus among both the scientific and lay communities in according the highest rank, in terms of prestige, to theoretical scientists. This may seem justified because theoreticians understand the thought processes and activities of the experimentalists, the laypeople, and even the artists, excepting perhaps poets, but the reverse is not the case. Virtually nobody can understand the theoretician. Thus, in order of prestige, after the theoreticians come the experimental scientists and then the technologists, but the lowest on the totem pole are the designers of hardware, of scientific instruments. This lowly rank does not seem to bother them, and they are happy in their field. As a matter of fact, many who earn royalties or actually manufacture the hardware are laughing all the way to the bank.

A more balanced view of the role of instrumentation is in order.* I well remember the fruitful meetings at the Gordon Research Conferences at Colby Junior College (New London, NH), where a group of people interested in instrumentation would meet and informally exchange ideas. The meetings included industrial chemists and physicists, academics, and manufacturers—sometimes more than one in a single person, as with Dr. Arnold O. Beckman, a frequent attendee. However, one day the instrumentation conferences were simply abandoned in favor of more narrowly focused disciplines such as "Gravitational Effects on Living Tissue," "Laser Interactions with Surfaces," and "Proteolytic Enzymes and Their Inhibitors," all topics of last year's conferences there. A similar fate befell the Instrumentation Section of the New York Academy of Sciences, which is no more.

Of course, instrumentation is a broadly interdisciplinary field that does not fit the narrow molds used by administrators and bean counters. Moreover, when you peruse the catalogs of laboratory supply houses, much of what is offered seems trivial. The Bunsen burner does not seem to be as great an invention as when it was first introduced. Even X-ray machines, which were deemed to be an absolute sensation a century ago when the mysterious radiation was discovered, seem mundane today, with every dentist using an X-ray machine. In truth, though, instrumentation is intimately and inseparably interwoven into the fabric of science and technology. Instrumentation is an essential element. It operates on all levels. At one extreme, instrumentation fills a recognized need, and at the other, it actually opens up and drives new directions in science and technology. In most cases, it is a mixture of both.

Only in retrospect can you judge the nature and the impact of new instrumentation. Looking back to my own youth, I remember working without pH meters. In engineering school in Germany, we were obliged to take advanced organic chemistry and were assigned to follow a novel synthesis, based on new literature. I drew an obscure pigment and had to follow a paper from the Rockefeller Institute. For weeks, I struggled to get a measurable yield, I finally found that in one of the many steps, the pH was critical, and when the pH was properly adjusted, the work went smoothly except that this was left out of the description. It cost me weeks of effort. Moveover, in those days, all we had were awful quinhydrone pH electrodes and primitive galvanometers with native amber insulators and Wheatstone bridges as potentiometers. I became enthusiastic about designing a glass electrode-based electronic meter and teamed up with an electrical engineering student to build a protype. We failed, of course, because of the very high grid currents of the old amplifier tubes. When I came to the U.S.A. after graduation, I found the older Coleman and the more advanced Beckman Model G pH meters in wide use. The pH meters were typically a need-driven development, as were the new spectrophotometers, which rapidly replaced the old visual and electronic colorimeters.

Not many years later, I was one of the first users of the new RCA transmission electron microscopes. One could argue that the need for higher resolution in microscopy existed. However, I think that it is fairer to say that the electron microscope arose from the desire to prove de Broglie's prediction, which was that a stream of electrons would have wave characteristics that could be translated into electron optics. And so we ended up with a spectacular new instrument and were trying to find uses for the unprecedented resolution. It was staggering, and much of the time, we were laboring to figure out what we were looking at. A more recent example is the laser. It, too, was an innovation that was looking for applications, and they came very slowly, despite the tremendous advantages of collimation and coherence of the laser light beam. Today, of course, lasers are everywhere, and a youngster could not imagine that a short generation ago people were seeking applications, when every laboratory, every office, and most every retail store has an abundance of lasers incorporated into their equipment. It is a typical case in which the instrument initiated the field.

This push-and-pull interplay threads through the industrial revolution. The steam engine, originally designed to pump water out of mines, became the mighty engine of this revolution. It revolutionalized not only transportation but also manufacturing and agriculture. The next big push came through the use of electricity, without which our present civilization would collapse. Currently, we are in the midst of yet another wave of an industrial revolution, based on microelectronics. But science and technology start in the laboratory, and laboratory instrumentation has a similar impact on industrial developments. I discussed this recently with John Atwood, Senior Scientist at The Perkin-Elmer Corp. (Norwalk, CT), who was involved in three major innovations: infrared spectrophotometry, atomic absorption, and, more recently, polymerase chain reaction (PCR, Hoffmann-La Roche, Inc., Nutley, NJ) instrumentation. He stressed that, when truly novel instrumentation increases the productivity of scientists and technicians in a given field by one or even two orders of magnitude, that field can expand up to 100-fold: a true revolution. Indeed, this is what happened over the past 40 years in chemical and material sciences. This revolution was partly due to new instruments dramatically speeding up old techniques, partly by their increasing the efficiency of industrial processes, and partly by enabling the development of entirely new products and production methods. As an example, chromatography comes to mind. First was Tswett's long-forgotten paper and the German "Kapillaranalyse," which was essentially paper chromatography. But when modern chromatography was reinvented, the field exploded with new applications and novel, derivative partition methods, including the newest capillary electrophoresis. Another striking example is clinical chemistry, which was suddenly automated, reducing tests from complicated analytical chemistry to routine, almost mechanical operations. It irreversibly changed the clinical laboratory and had a major impact on medical practice. Similarly, while molecular biology would have developed slowly and painfully by manual methods, modern instruments and associated new chemistries telescoped a distant future into a present reality.

We do not give daily thought to what life would be like without cars, planes, electric light, television, and computers. Similarly, we don't usually contemplate how Lavoisier and Priestly had to struggle in their laboratories. But we should, and then we would come to properly appreciate goo ldaboratory hardware.

* It is true that the Royal Swedish Academy (Stockholm) has awarded a few Nobel Prizes to inventors of new instrumental techniques, but there is ample evidence that instrumentation is not prized generally.

Reprinted from American Laboratory, March 1996

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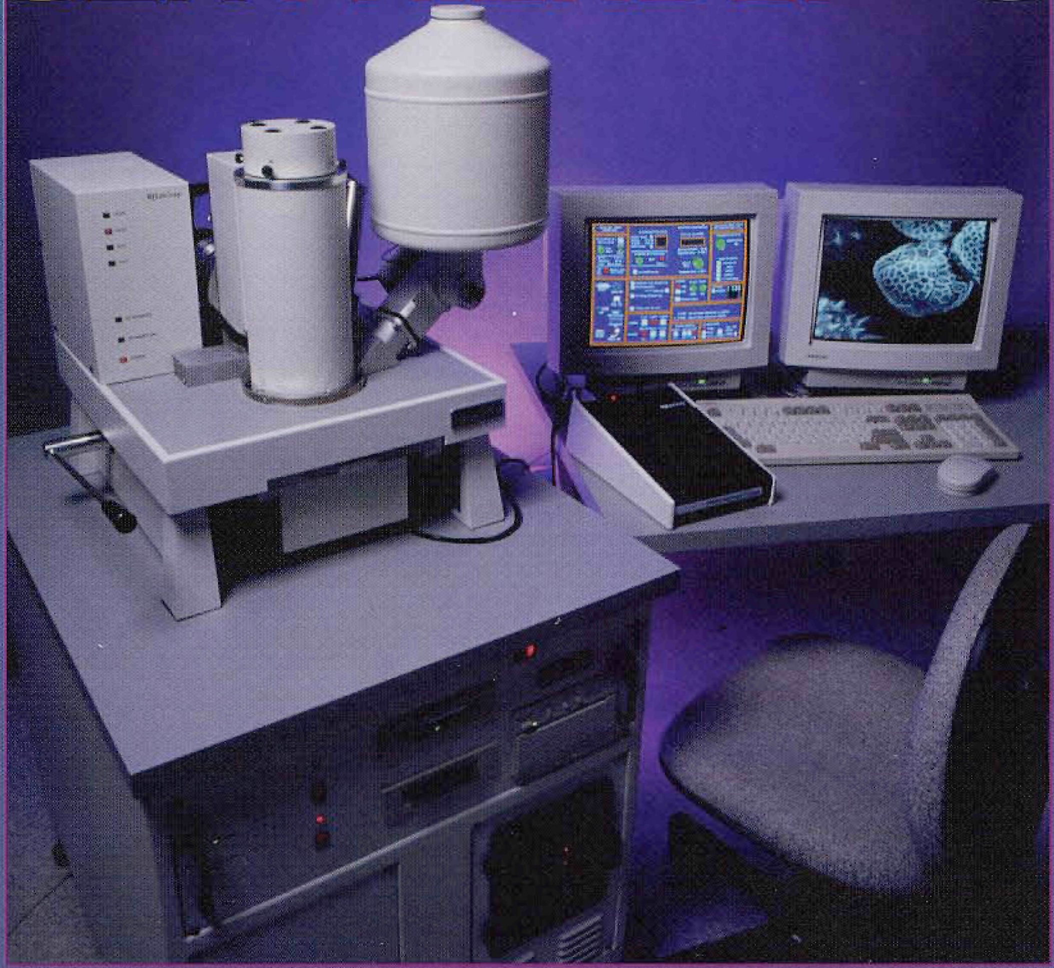

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