Wallace H. Coulter: Decades of Invention and Discovery

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J. Paul Robinson*

Abstract

Only a few inventors can be said to have made as great an impact on mankind as Wallace Coulter. His inquisitive mind and ability to see well beyond what existed served him well for 40 years of inventing. So many of the fundamental tools that exist today in the area of hematology were derived from or driven by Coulter’s inventions that he could be called the most technological innovator in the field of modern hematology. In achieving these discoveries Wallace Coulter was clearly capable of visualizing future opportunities that few others recognized. His vision was combined with an uncanny ability to translate his ideas into products. He developed a large number of tools that shaped the fields of cytometry, image analysis, and industrial materials. His understanding of the future power of computation drove him to link these technologies in a unique way. In the end, Coulter shaped the technologies that ultimately drove hematology in a new direction, one that remains on a critical pathway linking technology innovation all the way to true translational impact. It was said of Henry Ford that “[h]e has no notion that wealth has made him great, and any one who is impressed merely by his wealth bores him. In his personal contacts he likes to dodge the subject. He would prefer to talk with a machinist about machinery, or with somebody who likes birds about birds. In these contacts, he asks no deference; and if he gets it, he suspects it is mere deference to wealth, and that ends his interest.”¹ The same could be said of Wallace Coulter, who, like Ford, understood the concepts of mass production and customer service. Coulter had the ability to recognize the opportunity and fulfill the need for development of a blood-cell counter that could be placed in every pathology laboratory, and in so doing transformed a field from a qualitative to a quantitative environment. Every person who has ever entered a medical lab, hospital, or doctor’s office has felt the impact of Coulter’s discovery.

Introduction

Understanding the importance of the components of blood in the health and welfare of individuals is a process that has taken over 350 years; even now we still do not understand much of the complexity of blood. The pioneering microscopic discoveries of Van Leeuwenhoek have been beautifully described by Stein in his 1931 treatise on the subject (1). Interestingly, key to Van Leeuwenhoek’s role as an instigator of discovery was his ability to design and manufacture technologies—in his case a microscope-based one that was transformational in his time, being easy to manufacture even though rather difficult to use. Although it was not Van Leeuwenhoek who invented the microscope (Hans and Zacharias Janssen are thought to have done this in 1590), it was Van Leeuwenhoek who understood that making a reliable, simple-design tool was the key to increasing scientific knowledge concerning small objects at the time. Indeed, it is known that he manufactured hundreds of his “simple” microscopes (1) and published 110 communications to the British Society and 27 to the French Academy of Sciences, even though so important a scientist as Robert Hooke, whose treatise Micrographia (2) is far better known, restricted his own study to the use of compound microscopes, which had lower power than Van Leeu-

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Swammerdam discovered red blood cells in 1658 (3), other historical evidence refutes this claim; but Van Leeuwenhoek is known to have described blood vessels and his drawings were published in Philosophical Transactions (4). Indeed, it was Van Leeuwenhoek who in 1674 identified the disc shape of red blood cells (RBCs) in one of his communications to the Royal Society (1). Thus blood, one of the great unknowns in the

17th century, drove innovation and resulted in many biologically important discoveries.

Over the next 200 years, microscopes improved in quality and quantity, and small but important discoveries were made about blood. But not until Ehrlich’s time in 1877 was an automated and quantitative method for counting blood cells. The importance of Ehrlich’s work cannot be overstated, as he was the first to associate morphological information with cell type. Indeed, in the English translation of Ehrlich’s book Histology of the Blood, the preface written by G. Sims Woodhead states (5):

Ehrlich’s methods may be (and have already been) somewhat modified as occasion requires, but the principles of fixation and staining here set forth must for long remain the methods to be utilized in future work. His differential staining, in which he utilized the special affinities that certain cells and parts of cells have for basic, acid, and neutral stains, was simply a foreshadowing of his work on the affinity that certain cells and tissues have for specific drugs and poisons; the study of these special selective affinities now forms a very wide field of investigation in which numerous workers are already engaged in determining the position and nature of these seats of election for special proteid and other poisons.

Following Ehrlich’s definition of blood-cell types it took nearly 80 years before Coulter came up with the definitive automated and quantitative method for counting blood cells that has stood the test of time to this day. Counting blood cells had been a time-consuming and error-prone technique for nearly 100 years. Ehrlich had established a method that was accurate but statistically difficult, since manual counting was restricted by the limited number of cells that could be monitored. Coulter changed that by inventing a way to count tens of thousands of cells in a few seconds with ease and accuracy.

Blood—it’s All in the Blood

It was not until the mid 1800s that people began to take a more serious interest in blood. While attempts had been made to establish blood transfusions, the unique nature of red blood cell antigens was unknown, and remained so until Landsteiner’s red-cell classification and the fundamental knowledge of the antigentic nature of red blood cells (6) were published in the early 1900s.

What was the driving force for Wallace Coulter’s interest in blood? Coulter had spent nearly 3 years working in Asia and South America and had observed the conditions under which many people lived; it is clear that this perspective drew him to consider how he could create tools that improved early diagnostics such as blood counts. When he started to experiment with technology related to counting particles in solution, it is likely that he first reviewed the literature on then-current tools. Two types of optical instruments were available at that time—one that used color comparisons for measurement of hemoglobin and one that used a light source and an absorbance detector system primarily to determine cell concentration. Automation for other measures such as hemoglobin, white blood-cell count, or hematocrit was nonexistent.

Knowledge that had been accumulating over the years concerning many aspects of RBCs provided Wallace Coulter with hints as to an approach to accurate counts. One important and carefully researched piece of information was the nature of the conductivity and permeability of red blood cells. Much of this work was done in the early 1920s by S. C. Brooks at the US Public Health Service in Washington, DC. Brooks noted that electrolytic conductance of cells had been used as a measure of their permeability (7). Little was known about the biochemistry of red cells or the nature of red-cell membranes at the time. Much of Brooks’s work involved trying to accurately determine the actual volume of RBCs and testing the various methods for such a determination. Brooks essentially showed that the only accurate method for determining red-cell volume was in fact the hematocrit method.

It is generally accepted that the modern hematocrit was invented by Maxwell M. Wintrobe in 1929 (8). His measure consisted of a special graduated tube (named after the inventor) that was able to measure the volume of red blood cells in blood as a percentage of the total blood volume. Wintrobe’s tube simplified the measurement and was standard until faster centrifuges allowed capillaries to be used instead. In addition, Wintrobe went on to classify mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC), all of which were important measures of patient health for many years. These measures continued to be performed over many decades, essentially using the same techniques, all manual and all time consuming. By the mid-1950s, a variety of different tests were being considered for blood-cell measurements as noted earlier, including optical techniques. Automation was clearly desirable because of the objectivity of the result. Measuring color differences between a tube and a color standard appeared to be one of the few automated methods available, but the method was known to have a significant error, perhaps less than manual counting but still not acceptable.

When we look back on these developments, it is not surprising that each was essentially an iteration of the previous technology, something that is seen frequently in science and engineering technology development. Indeed, all the above individuals iterated a counting chamber numerous times, and this did not change until Moldavan attempted to create an electronic counting chamber in 1950s, a variety of different tests were being considered for blood-cell measurements as noted earlier, including optical techniques. Automation was clearly desirable because of the objectivity of the result. Measuring color differences between a tube and a color standard appeared to be one of the few automated methods available, but the method was known to have a significant error, perhaps less than manual counting but still not acceptable.

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decades, most attempts at measuring cells were focused on photoelectric devices, which basically used light scatter to determine the number of particles. These included Gucker’s work derived from mine-dust studies (10) and the work of Crosland-Taylor (11,12). The common aspect of these studies was the focus on development of stable sheath flow—a principle that was to become embedded within flow cytometry development.

With the exception of Moldavan and Gucker, most of the above pioneers in hematology were medically trained and their discoveries had significant impact, but it is arguable that Wallace Coulter, a person with no medical degree, had the most impact on the 20th-century processes by which patients were evaluated. In being the first person to develop fully quantitative and automated tools to rapidly extract key information from blood and deliver it directly to the physician, this low-key engineer changed the practice of hematology by creating systems that were determined to be both accurate and reliable. By identifying a fundamental problem in performing accurate counting and creating an innovative solution, Wallace Coulter made an impact on patient evaluation as fundamental as Landsteiner’s blood groups were to transfusions, and Kohler and Milstein’s (13) were to immunology. The amazing technological changes that occurred in the last half of the 20th century were without doubt driven by Coulter’s “big-picture” attitude toward the role of technology in patient treatment.

KEY INVENTIONS

The Coulter Counter

The early history of Wallace Coulter’s life provides some insight into his future successes. His earliest jobs, working for a Memphis radio station as well as for the Press Wireless Radio station in New York, gave him some early training in the hardware and its applications. This knowledge was fundamental to his future development of blood-cell counters. After World War II, Wallace Coulter worked for several electronics companies, including Raytheon and Mittleman Electronics in Chicago. Over the post-war years Wallace put his attention to a number of projects that involved electronics and optics, and all of them involved his designing and building amplifiers, pulse generators, and oscillators. Archived documents held in the WHC Foundation make it clear that some of Coulter’s attention was focused on basic material science in the late 1940s and early 1950s. At this time he began to consider the use of particle-size analysis for counting red blood cells. Coulter would have been aware of the several examples of particle measurements being made using optical techniques, such as that of Gucker mentioned above (10), and of course Moldavan (9). The predominant technique for particle and cell measurement was by optical means using a light source. Particles blocking the light source would provide a signal. Early work by Coulter tried to repeat these experiments using optical systems. In fact, from the various personal reports available, it is clear that Wallace Coulter was testing a variety of product-development ideas across several different fields.

He maintained a laboratory/workshop initially in the basement of his home to work on promising ideas and projects even while initially he was employed in a full-time job. His father (Senior) and brother (Joseph) were not involved in the early days. This basement lab was primitive and crowded even with just a few of Wallace’s employees. There was no specific direction in his business; in the early days, Wallace Coulter was playing with amplifier design and sterilization systems, as well as particle-counting ideas. He eventually rented additional space a few blocks from the basement workshop and established an engineering group so that specific projects could be focused. This separation of his engineering group and his small manufacturing group was not an ideal situation.

At the time, the Office of Naval Research (ONR) had identified a significant problem in the composition of paint for their battleships. Different batches of the same color paint had slightly different hues—something that was not acceptable to the Navy, considering the thousands of gallons needed to paint a single ship. Paint, like toners (on which Wallace Coulter also worked for Xerox Corporation), contains a variety of tiny particles that must be of consistent properties. Unfortunately there were no good quantitative methods for studying the size distribution of solid particles at this time. Wallace thought about the Navy’s problem and figured that standardizing the number and size of solid particles in paint would be a key factor in establishing the final hue of paint batches. To achieve this required an instrument that could repeatedly measure particle concentration accurately. Wallace eventually had a contract with ONR,2 for whom he built a test particle-counter instrument.

The first commercial counter that Wallace designed was the Coulter counter Model A (Fig. 1A) and the first 300 of these instruments were sold to research labs. Figure 1B shows the hand-drawn ideas for advertising this instrument. Interestingly, these were designed not for red blood cells (RBCs), but for white blood cells (WBCs), as the latter were generally considered at the time to be more important than RBCs in clinical diagnosis. The major publication and review of this instrument was by a group of scientists led by Carl Mattern from the National Institutes of Health. Oddly enough, the Office of Naval Research (ONR) was again involved. ONR contracted with Coulter to manufacture one of his instruments, which was then sent directly to Mattern’s lab at the National Institute for Allergy and Infectious Diseases (NIAID) to test [see footnote 4 of (14)]. NIAID was formed in 1948,3 so it is impressive that within its very early years it became the test bed for a technology that proved transformational for hematology. Further, the instrument was so impressive to this team of leading researchers of the day that it was immediately passed on to a second team at the National Cancer Institute, where a second report was published by George Brecher and his group just 2 months

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2An experimental model of the Coulter Counter was constructed under Office of Naval Research Contract NONR-10541(00)
3http://www.niaid.nih.gov/about/whoweare/history/Pages/SixtiethAnniversary.aspx
after the first paper (15). The significance of Coulter’s technology was immediately clear. Although the counters were originally manufactured from Wallace’s basement site, the lack of space and the fact that his engineering and manufacturing were separated, eventually forced the lab to move both groups into a couple of floors in a new building standing beside a four-track railway line in Chicago. While the space was better than the original basement and allowed a significant increase in work force, every time a train passed by the building all testing ceased; because of the severe vibration instruments could not be calibrated and work essentially stopped. Nevertheless, many Model As were manufactured at this site, although according to Robert Klein (16), the chief engineer at the time, the Model A had some severe electronic limitations; it did not have amplitude stability, and thus particle sizing was highly inaccurate. One of the innovative solutions Wallace devised was to put two apertures on the A – one normal size and the other very small. The latter would count a higher number than the former; however, since the volumes of both apertures were known, the difference between the two allowed them to extrapolate the curve to zero to determine the true count. A series of charts were drawn to enable the user to identify the real count by applying correction factors.

Wallace naturally recognized the problems in the Model A, which could not size particles, and attempted to correct them in the Model B (Fig. 2). The primary advance was the creation of amplitude stability so that particle sizing was accurate. One advantage that Wallace now had was that many instruments were already in the field, and users themselves were identifying potential modifications that would change or improve instrument performance. The Model C developed subsequently was designed for industrial use and was never intended to be a medical device. It was an enormous instrument (Fig. 3) with two racks each containing 12 relays, each with motor-driven potentiometers and a large number of power-hungry vacuum tubes, the entire unit consuming 20 kilowatts – sufficient power to drive 4000 of today’s iPhones simultaneously. Only a few were built, but it was a state-of-the-art instrument and an important one in Coulter’s advanced technology development program. The Model FN – only the 4th iteration of the Coulter counter (Fig. 4) – was released in 1968. This was a fully transistorized version of the

Figure 2. The Model B Coulter counter. This was a major modification of the Model A and was designed to accommodate many of the problems in the Model A.
Model B, in which the 50-plus valves of the Model B were reduced to small circuit boards populated with transistors, and became the most critical instrument for the small hematology laboratory.

The electronic counter business was so successful that eventually in 1958 Wallace had the resources to move the entire business to a warmer climate and relocate in Hialeah, Florida. During the time in Chicago they had developed the Models A, B, and C and established a strong manufacturing and distribution chain around the country and indeed around the world. It was clear to Wallace Coulter that his technology was a vital component of medical diagnostics now that the instruments were firmly ensconced within the hematology field.

The Cell Sorter

Although Wallace Coulter was not involved in the invention of the cell sorter, his impedance-based cell-counting technology was the basis for the invention by Mack Fulwyler (17). The history of the invention of the cell sorter is firmly entrenched within the fields of cytometry and immunology and as such shows how transformational Coulter’s ideas were. The story has been told by Mack Fulwyler in a recent article based on video recordings of Fulwyler’s discussions (18) on development of the original cell-sorter technology (19).

Fulwyler’s interest in designing a cell-separator instrument was based on work going on at the Los Alamos Scientific Laboratory (as it was called in those days) during a time when a huge amount of attention was focusing on the impact of radiation on health and welfare. Of particular interest were changes in blood-cell numbers and function. A pathologist by the name of C.C. Lushbaugh in the laboratory had been working with one of Wallace Coulter’s 100 μm–orifice Coulter counters. These instruments had been available in the market place for several years and had made their way into both clinical pathology laboratories and research faculties. Lushbaugh’s environment at Los Alamos was one where a vast array of developmental technology was available. Using these electronic resources, Lushbaugh had integrated a 100-channel pulse-height analyzer (PHA) onto the Coulter counter, giving him multi-dimensional data from the blood-cell counts. Lushbaugh believed that he had identified a bimodal population of RBCs and published the resulting distributions (Fig. 5) in a 1962 paper (20). Over a period of two to three years a significant discussion arose within the laboratory questioning Lushbaugh’s interpretation of his bimodal distributions. Several papers were published, including Leif (21) and Van Dilla (22), suggesting that the bimodality was an artifact resulting from the increased aperture voltage that Lushbaugh had applied in order to gain more signal for his pulse-height analyzer (22). During this time Mack Fulwyler was working in the laboratory; as an engineer he carefully evaluated the experimental design of Lushbaugh’s study and determined that the instrument may have been inappropriately adjusted, resulting in the creation of false distributions. Fulwyler noted that Lushbaugh had already shown that there was no apparent microscopic difference within the RBC populations. He decided that the only way to provide proof that the bimodal populations were different would be to physically separate them. As no technology existed for such a task, in 1963...
and 1964 Fulwyler investigated the opportunities for designing an instrument to accomplish this separation.

Since the discriminating technology was the Coulter principle, Fulwyler established that this must be the fundamental method for separation of the RBCs. Then he heard about the invention of Richard Sweet’s electrostatic chart recorder. Sweet, working on a program funded by the US Signal Corp., was attempting to record frequencies that were too high for standard chart recorders that used pen-type traces. He thus designed a piezo-vibrating module that fired tiny droplets of ink onto the paper and could operate at very high frequencies. When linked to the signal amplifier, the head would be responsive to changes in voltage; a stream of ink would follow the changes in voltage, thus creating his recording “oscillograph” – the earliest inkjet printer (Fig. 6). In a series of letters exchanged between Fulwyler and Sweet in 1964, it became apparent that Fulwyler’s best chance of building a cell-separation instrument would be to integrate Coulter volume into a custom-designed piezo-driven inkjet-type head. Fulwyler achieved this feat in just a few months and created the first electrostatic cell sorter, the origin of today’s wide variety of sorters.

Radio-Frequency Opacity

Perhaps because of his inquisitive nature or because he had started his adult life working in a radio station, Wallace linked radio frequency and Coulter volume to come up with a term he called “radio-frequency opacity.” His initial ideas were that Coulter volume would measure size, as was fundamental to his technology, but the addition of a high-frequency component would allow for a signal that correlated with impedance, would be a radio frequency–derived measure, and would represent the “opacity” of the cell. His first patent in this domain was filed in 1966 and issued in 1970 (29); this was to be the earliest implementation of a technology that became one of the core hematology technologies of Coulter Electronics and has remained so to the present day. Wallace Coulter reasoned that by adding new signal measurements it would be possible to both reduce the noise associated with measurements and determine different properties of cells. At this time, lymphocytes were classified only as “small” and “large”; other white cells were better known in terms of functional capacity because they were more easily differentiated by morphological means. It is clear from Coulter’s original patent application that his goal was to create a more comprehensive system of


4http://www.cyto.purdue.edu/cdroms/cyto10a/cytometryhistory/individualhistories/media/fulwyler/mfphd.pdf
cellular classification. His thought was that phase differences as well as amplitude differences could be collected using this new detection toolset. Further, Coulter anticipated that multiple frequency components might be present in the sensing region, depending on the energizing current, and that several of the components could be isolated by “virtue of their different frequencies as well as phase” (29). Coulter hypothesized that for a particular radio frequency “one of the two components separable by phase difference may be produced primarily by the reactive effect of the material from which the particle is made and the other is produced primarily by the resistive effect of the material from which the particle is made” (29). Coulter believed that using what was essentially a “multiplexing” concept would provide more details about the nature of the cells. He utilized the terms “resistive” to describe DC impedance and “reactive” to describe AC impedance, believing that functional properties could be measured on his instruments. It should be noted that this patent application came just after Fulwyler published his cell-sorter paper in 1965 and just a few years after Coulter had moved his operations from Chicago to Hialeah; by this time he was heavily engaged in manufacturing instruments for both research and clinical laboratories.

Clearly Wallace Coulter was always trying to find opportunities to improve the Coulter counter. The major advance, the Coulter S, had been planned for some years. In fact, the concept and theory for the Coulter S had been developed in Chicago about 1958 prior to his moving to Florida. Interestingly, although some of the technologies required for the S were not even developed, yet the concept of the fully automated, multiparameter hematology instrument was clear in Wallace’s mind. Indeed, Wallace pushed his engineering team to move in the direction of full automation. The opacity technology would become key for future expansion of Coulter technologies. Wallace Coulter’s uncanny ability to see well ahead of the present time is evident within his patent #3,502,974, submitted in 1986 and issued in 1988 (30). Fundamental to this technology was the ability to distinguish between particles of identical size but different composition. This multimodal concept allowed Wallace to expand his instruments to produce new quantitative measures not pre-

Figure 7. Mack Fulwyler used Wallace Coulter’s Coulter principle as the basis for identifying different red blood cells in his cell sorter invention from which this figure is reproduced. On the left is the figure from Fulwyler’s patent #3380584 and on the right a photo of one of Fulwyler’s actual sorting heads made in 1969 and now in the laboratory of the author. The lower part of the device contained a platinum disc for conductivity measurements and the plastic acoustic horn in the center transmitted the piezo pulses down the chamber to amplify the power of the vibrating piezo to effect the droplet creation.
viously possible, even as others were starting to become major competitors in the very field that he created.

**Hemoglobin Analysis**

Patent US4250051 (1978) issued to Douglas Armstrong and assigned to Coulter Electronics covered a method for accurately determining hemoglobin concentration based on the use of saponin-based red-cell lysis and a stabilization technique to retain the state of hemoglobin. While this process had been around for many years, it appears that company’s approach resulted in a highly controlled and reproducible process for large-scale manufacturing.

Wallace had actually been using saponin for lysis as far back as 1949. While it is not entirely clear where he got this idea, it had long been known that saponin was a good chemical for lysing red blood cells. In fact, a considerable volume of work had been done by Fricke and Curtis in 1934 (31) on this very topic. These investigators were studying the electric impedance of hemolyzed suspensions of mammalian red cells. Indeed, the discussion section of this paper shows a deep knowledge of the properties of red blood cells and the roles of various lysing reagents, saponin being the most significant. This sort of information was most likely available to Wallace Coulter. Had he searched the literature, he would have identified this manuscript. Further, since the paper was written by biophysicists, Wallace Coulter would have fully understood the implications, whereas some biologists quite likely would not. In addition, the close relationship between the electrical properties of cells and the potential measurement possibilities that Ponder proposed is clear and identified in this report. Obviously, Wallace Coulter recognized immediately that the reagent was at least as important as the instrument, and the saponin lysis reagent was one of the first reagents Coulter made; it is still sold to this day. One wonders how many vials of saponin have left the various Coulter factories around the world in the last 60-plus years.

**The Navy and the Coulter Counter**

Several interesting notes have been made about how Wallace Coulter gained credibility across different aspects of the scientific culture. One of these aspects was the Office of Naval Research. A number of stories have been written about his interactions with the Navy, but not all can be completely confirmed. We do know that Wallace did have a contract with ONR; the NIH scientists who evaluated the Model A indicated that the instrument they received came directly from ONR, as noted earlier. Reference has already been made to the use of his counting technology to test the particulate components of paint for the Navy in his basement lab. Another version is that while playing with paint, he came to the conclusion that blood could be interesting as it had a consistency similar to that of some paints he was testing. It is unknown if either of these stories is accurate. Regardless of which (if any) of the above stories are true, it is clear that Wallace Coulter left no stone unturned in his push to increase the impact of his technology in all aspects of research and testing. The work Wallace did for the Navy clearly demonstrated the value and importance of accurate counting technologies. This industrial aspect of Wallace’s business was one that he aggressively pursued. In fact, in an April 1, 1959, advertisement placed in Analytical Chemistry, Coulter stated that the Coulter counter was “in over 50 leading industrial laboratories since it was first announced” and also claimed over 200 in the medical-biological field. Two years later in an October 1, 1962, advert placed in Analytical Chemistry, Coulter claimed that there were already 1,500 installations of his technology.

**Intellectual Property Protection**

Wallace Coulter was more than a good engineer. He was also a good businessman and he paid a great deal of attention to protecting his inventions. One of the earliest challenges was in the late 1950s from the Los Alamos Scientific Laboratory (LASL; now the Los Alamos National Laboratory, LANL), where the pathologist C.C. Lushbaugh was using a Coulter counter for a variety of measures, in particular the study of red blood cells. He had linked the latest multichannel analyzer to the instrument in the hope of being able to separate the pulses generated on the oscilloscope into different channels. He surmised, correctly, that different pulse heights represented specific features of cells and that he could identify differences in populations using this single-parameter, multichannel option.

His publications (20,23) naturally drew Wallace’s attention to this work using his technology. Wallace identified at least two primary issues—one scientific and one business related. First, Wallace did not have an instrument with a multichannel analyzer, and this was clearly a need; but second, it was clear to Wallace that the scientists and engineers at LASL were building their own impedance-based technologies and he was very concerned that they may have been infringing his patent. He immediately sued the lab to protect his technology. Eventually, the suit was withdrawn when Wallace realized that Los Alamos was doing research on the technology and had no intention of commercialization, or any mechanism at that time to do so. Coulter Electronics proceeded to provide the Lab with several glass probes with different-sized channels and shapes to help promote the work (Scott Cram, personal communication). As a result, several of the scientists at LASL, including Marvin Van Dilla, Mack Fulwyler, and Scott Cram, became consultants to Wallace Coulter. In this way, Wallace both promoted and protected his technology while at the same time having one of the leading technology institutions in the nation working by his side.

Throughout his life, Wallace Coulter vigorously enforced legal protection of his inventions. He understood the nature of competition and over the years was engaged in various litigations, some of which he won and some of which he lost.

**Wallace Coulter’s Impact on Flow Cytometry**

After Fulwyler completed the first cell sorter in 1965 he moved to the University of Colorado with his new instrument to complete his PhD. In 1969 he returned to Los Alamos, where he was the principal investigator on a project funded by the National Cancer Institute to automate detection of cervical cancer using flow cytometry and cell sorting. However, there
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was a conflict of interest related to his consulting with Wallace Coulter. Seeing an entrepreneurial opportunity to commercialize the cell sorter, Fulwyler decided to leave LASL in late 1971 and start Particle Technologies, Inc. (PTI), a small start-up funded directly by Wallace Coulter as a wholly owned subsidiary of Coulter Electronics.

By this time, Wallace had built a very large company in Florida and was intimately involved in anything related to particle or cell enumeration. Wallace had closely followed the situation at Los Alamos, as he carefully monitored use of his Coulter counter technology and was not prepared to lose control of it. Funding Fulwyler’s company was a mechanism to advance the technology and maintain control of this rapidly changing area. In addition, Wallace recognized the need to produce microparticles of precise dimensions, and this was one of Particle Technologies’ product lines.

Particle Technologies was focused on transforming Fulwyler’s sorter into a commercial entity. Mack hired engineers who set about building big instruments. Fulwyler’s original sorter was an enormous construct—typical of the valve amplifier technology and the array of large component instruments that put together made up an analytical instrument. There is now strong evidence that Fulwyler and Van Dilla, and probably others at LASL, were actively working on fluorescence analysis within a few months of completing the original cell sorter in 1965. In fact, it is reported in the Smithsonian documents (18) that Boris Rotman visited the labs about 1966 and persuaded Fulwyler to build a cell sorter with fluorescence capacity specifically for him. Rotman had already published an assay based on fluorescein-derived fluorogenic substrates for beta-1,4-galactosidases and phosphatases in 1963 (32); based on Rotman’s discussion in the Smithsonian documents (18) it is clear that when he visited Fulwyler soon after the publication of Fulwyler’s sorter that an agreement was reached for Fulwyler to build a model of the original instrument. Indeed, the instrument manufactured and delivered by Fulwyler to Rotman at his new laboratory at Brown University in 1967 was a fluorescence-based instrument with a single PMT and cost around $5000 at the time. By no later than 1967 Fulwyler was working with acriflavine-feulgen staining to measure DNA content and Coulter volume; subsequently fluorescence analysis became the method of choice for cell separation rather than Coulter volume (33,34). Fulwyler’s goal was to integrate both Coulter volume and fluorescence detection into his instruments. It was clear that Leonard Herzenberg at Stanford was working toward the exact same goal. It is interesting to observe that the decision of Wallace Coulter to start Particle Technologies with Mack Fulwyler on October 1, 1971, came at almost the exact same time as Becton Dickinson Electronics Laboratory was negotiating with Herzenberg to collaborate on his projects, the agreement for which occurred between November 3 and Dec 15, 1971. In 1972 Herzenberg published his seminal paper demonstrating fluorescence-based cell sorting (35).

Within a year, Fulwyler hired Bob Auer to help advance his technologies, all fully funded by Wallace Coulter. Shortly after Auer arrived, John Glasgow, the engineer building the two-parameter analyzer (TPA) left the company. This moderately small unit (about the size of two regular Coulter counters) was to be manufactured in Hialeah (Robert Auer, personal communication). There was a problem, however, as the technology was considerably more complex than the blood-cell counters produced in Hialeah, and no progress was being made. The project, along with the two-parameter sorter (TPS) (Fig. 8), was then handed to Auer to develop in Los Alamos and subsequently transferred to Hialeah. At the same time, other engineers were working on several large instruments, one being charmingly called the Super Dooper Sorter (SDS-1), a huge instrument capable of 2 colors of fluorescence, forward scatter, and Coulter volume and operated by a PDP 8 computer console with graphics displays and a Tektronics 4010 display. The computer and display occupied three six-foot-high instrument racks. Data and protocols were stored on Tridata cartridge tapes (Robert Auer, personal communication). Excitation was via a Spectra Physics 164 five-watt argon laser. A second prototype of this instrument used a Spectra Physics 162 fifteen-milliwatt argon-ion laser and also used the PDP-8 computer data-acquisition system. A third prototype, called the SPA-1, was a single-color fluorescence-only analyzer with the same Spectra Physics 15-mW argon laser as well as a hardwired pulse-height analyzer (Fig. 8).

In November 1973, Coulter and his leadership team visited Los Alamos on the way to the Engineering Foundation meeting on analytical cytology in Asilomar. In attendance were Robert Klein and Walter Hogg, the chief engineer for Coulter Electronics. Apparently, Fulwyler was pushing hard at this meeting for Coulter Electronics to support the large cell sorters, which he saw as the core instruments that would drive biological innovation. Wallace’s team apparently did not accept this philosophy and were more inclined to favor the smaller, more portable instruments that they had promoted.
for the hematology market. In April of 1974, Coulter had a major display of both the TPA-1 and the TPS-1 instruments at the FASEB meeting in Atlantic City. Becton Dickinson was displaying their first FACS instrument at the same meeting and had advertised that they would be the only company to demonstrate a commercial flow cytometer. Characteristically, with his typical pride of leadership Wallace had made the decision that his company would also display at their booth and had driven the team hard to prepare the instruments in time. What is interesting is that these were relatively small instruments, in keeping with Wallace’s principal philosophy that if you can’t put the instrument in the back of a station wagon and take it to a client’s laboratory, you won’t be able to sell it. Both were small and compact and looked very much like “big Coulter counters.”

The goal was to transfer the technologies of both the TPS and TPA instruments for production at the Hialeah manufacturing site by the end of 1974. There were significant problems in their production, however, and Auer was asked to continue engineering in Los Alamos till the summer of 1975, when four redesigned prototypes of the TPS-1 were delivered to Hialeah. One of these went to Dr. Jerry Hudson at the Miami VA Hospital and one to Dr. Leon Wheelless and Dr. Paul Horan at the University of Rochester. One of the new features of the redesigned sorter instrument was a new scatter sensor patented by Coulter Electronics (36) that used a Fourier lens to reduce sensitivity to alignment and whose response was monotonic with particle size.

Although Fulwyler started Particle Technologies and was president of the company, he was still a consultant, not an employee. Since Wallace owned the company while Fulwyler managed the operation, Wallace and his team had the final say concerning the direction taken by the company. Fulwyler, however, had a very broad spectrum of interests; one that excited him was the utilization of concepts like, for example, a live/dead cell enumeration system based on detection of Trypan Blue exclusion. Such a system was already associated with Kamentsky’s Bio/Physics Systems’ two-parameter red laser-based Cytograf, which was manufactured beginning in 1970. Key to this concept of live-dead discrimination was the combination of forward scatter and extinction, which led to the idea of “diagnosis on a microsphere” in which microsphere substrates would hold antibodies and target antigens for diagnostic tests. Fulwyler, like Coulter, had a strong interest in developing diagnostic tools for a wide range of human diseases. His patent application in the USA failed because of a conflicting patent held by Technicon, but it was subsequently issued in the UK.

Fulwyler’s input from customers was that large instruments would become the standard. In 1974 Fulwyler obtained a contract from NIH to build and deliver a large multiparameter sorter to Dr. Chet Herman at NCI. In a letter to the NIH procurement branch on May 24, 1974, James Corll of PTI discussed the issuance of an NIH contract to PTI for a “biological cell sorter.” In this letter he states:

These devices are very complex and of such recent development that the terminology—the very words, names, and function descriptions—associated with such devices is still not universally understood or accepted.5

The SDS-1 prototype was converted into what was called the Electronically Programmable Individual Cell Sorter, or EPICS II, and this unit was subsequently shipped to Dr. Chet Herman at NIH in 1974 (Fig. 9). Clearly, Fulwyler was moving at full speed to capture what he considered to be a potentially huge market for cell sorters.

This philosophy, however, did not fit well with Wallace Coulter. Wallace Coulter’s history in working with small portable instruments had focused his philosophy. If there was anything that one could say was fundamental to Wallace it was the concept of being able to personally demonstrate instrument operation in the client’s lab. Thus the instrument had to be small and portable. When Wallace saw the huge size of cell sorters, he and his engineers, particularly Bob Klein, decided that was not the direction they wanted to go. Fulwyler had spent 1973 and 1974 developing moderately large instruments. It was difficult to focus on small instruments, since the primary source of light excitation was a large Spectra Physics Model 164 4-watt laser that was several feet long and commanded a power supply weighing about 100 lbs with water hoses and 208v power cables. At this time Fulwyler was focusing on the TPA-1 and TPS-1 and was working with his consultant scientists at Los Alamos: Marvin Van Dilla and Scott Cram.

All successful people make decisions that don’t work out as intended, and some of their decisions put them at a disadvantage. Wallace was no exception. The initial decision Wallace made not to pursue huge, expensive cell sorters was a monumental one. It resulted in the closure of Particle Technologies—the company that Wallace funded and Mack Fulwyler ran. To a large extent, this decision allowed Becton Dickinson to manufacture and sell large instruments without significant competition for about five years. During this time Coulter realized that he had made a serious mistake and eventually changed his

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5Letter dated May 24, 1974 from James A Corll of PTI to Mr. Sherman Oxendine, NIH – Procurement Branch, Building 13, Room 2W54, Bethesda, MD 20014
Fulwyler’s Vision of Flow Cytometry

Fulwyler’s plans for cell sorting were outlined in a detailed document sent on August 24, 1973, to Wallace and his team in Hialeah. He defined the plans for a large cell sorter that had two fluorescence detectors, a light-scatter sensor, and a Coulter orifice for impedance measurements. The goal was to establish PTI firmly in the cell-sorter business. In this document, Fulwyler stated that the above instrument was already under construction but that a decision would be taken later as to whether a model for sale would be constructed. His estimate for the sale price of such an instrument was $70-90,000 in 1973. His primary task, however, was to convert the TPA (analyzer only) instrument into the TPS—a small sorter which would become their primary commercial product. This instrument would have a 10-mW argon laser, with a 50-mW alternative. The instrument was very advanced, with a 128-channel analyzer, pulse-ratio analysis, scatter and fluorescence gating circuits, count registers for both light-scatter counts, fluorescence counts and counts for the number of cells sorted, preset count levels up to a maximum of 100,000 counts, volume analysis for absolute counts, and finally sorting by any single gate on any parameter collected. He proposed to have the first unit for delivery by April 1, 1974.

The visions of Fulwyler and Coulter, however, were too different to be resolved, and it was decided that the company would be dissolved and employees relocated to Florida in March, 1975. Mack Fulwyler was immediately employed by Wallace’s chief competitor, Becton Dickinson, as a research director but had to spend almost a year in Germany at the Jovin laboratory to comply with his no-compete contract as a consultant. Upon his return Fulwyler worked at Becton Dickinson for a short time on flow cytometry instrumentation. Once in Hialeah, Bob Auer proceeded to develop the EPICS instruments—and with the exception of the TPS the first several instruments were large, expensive technologies. Auer kept these projects going in “the back room” of engineering. Only a couple of years later Wallace changed his mind and determined that this was a business important to him; the EPICS instruments became the premier line of Coulter’s flow cytometry division.

Regardless, Wallace recognized that the world of flow cytometry was not the same as that of clinical hematology— it had its own unique path to take before it emerged as a key part of clinical hematology. It would be no surprise that Wallace saw that many of the technology developments of flow cytometry would become keys to the future of hematology instrumentation. He used the flow cytometry inventions and innovations to drive the hematology instruments from which the greater part of his business success was derived. Wallace may have made a bad decision to drop the large technology that was clearly driving the world of flow cytometry; however, as soon as he was convinced that this level of instrumentation was necessary to advance new discoveries he endorsed the large, expensive instruments, and invested heavily in their success.

Seven-Part Differential

The Holy Grail for hematology was to develop fully automated multipart measurements on a blood sample. This was achieved by Coulter’s patent filed in 1967 and issued in 1970. Directly from the patent:

The first size parameters are classically referred to as the red blood cell count (RBC), the hematocrit (HCT), the hemoglobin (HGB), the mean corpuscular volume (MCV), the mean corpuscular hemoglobin (MCH), and the mean corpuscular hemoglobin concentration (MCHC). The seventh parameter is the white blood cell count (WBC) (37).

The move toward full automation required many components that were immature or not even developed, yet Wallace and his team set the goal of full automation. It was Wallace’s vision that automation was the only way in which accuracy could be accomplished in medical instrumentation. During the development of the Model B and Model C Coulter counters, every process undertaken was with the goal of implementing an instrument that could provide a plethora of results directly to the doctor. The result of all this work was the Model S—the “S” stood for “Senior,” the common reference name used for Wallace and Joseph Coulter’s father. “Senior” as that time managed the accounts for the business in Chicago. The Model S also drove the company’s move to Florida and into a huge industrial building—a beer storage building, no less! It was here that the S was finally manufactured.

The design of the Coulter S would not have been possible without the discovery of the integrated circuit (IC). Up to this point, the most complex Coulter counter built had been the Model C, a huge industrial instrument that (as noted earlier) consumed 20 kilowatts of power (see Fig. 3). Such an instrument with its huge valve racks would not be acceptable or cost effective for medical laboratory use. The integrated circuit was developed and patented in 1959 by Texas Instruments. Amazingly, in 1968 when the Coulter S was released to the market, the 1,200 semiconductors in each instrument and the total production of the Model S in that year accounted for 5% of the worldwide production of ICs (16). The Model S became an overnight sensation in the world of hematology, forcing Wallace to rethink his financial operations. Up to this point, manufacturing had been entirely supported by the sale of instruments. Stocks of parts were purchased only as instruments were sold. The Coulter S was revolutionizing the industry, but was also driving competition. By the 1970s, the patents on Coulter volume were expiring and many companies were adopting this technology essentially free of charge and making copies of the famous Coulter counter, forcing Coulter always to integrate new ideas that would extend the life of his technologies.

The success of the Coulter S was an important turning point for automation. The S (and its many updates and enhancements) was the most successful instrument ever in hematology. Numerous papers were written comparing it to its competitors (38–41), and the Model S was both transformational in itself and in driving competition. Full automation was now standard within the hematology laboratory for both blood counting and blood chemistry—an area driven by
Wallace’s competition as well as his own company. Following the enhancements of the S were platelet counts, a variety of new instruments for differential counts, and automated reporting. The entire field at this time in the 1980s focused on increasing the number of parameters measured and was driven by the need for detailed and documented reporting.

Lab automation demanded total automation, including closed-tube sampling, bar-code identification, and parameter profiles of as many as 16 parameters, including CBC, WBC, differential, platelet count, and evaluation of red cell abnormalities with <1% false negatives, something achieved by the end of the 1980s. The STKS instrument, developed by 1989, incorporated the opacity technology previously developed, with a 20-parameter profile fully automated at 100 samples per hour—the most sophisticated hematology instruments available.

Wallace had achieved his goal of full automation with high accuracy and lower cost per test. It took 40 years of intensive development from the time he tested his Model A to the time the STKS was installed in the largest hematology labs in the country. Most of the tests performed by the advanced S-type instruments were not considered possible when Wallace introduced the Model A.

Standards in Hematology

An excellent review of the establishment of standards in hematology has been written by Lewis (42). The process began with a committee organized by a group of individuals at a meeting in Lisbon in August 1963. As noted earlier, there was considerable confusion as to which quantitative measures were correct. Haldane had established one method that became standard in the UK with a hemoglobin measure of 13 g/dl, while others in Europe used 17 g/dl, and in the USA yet a different measure. As described by Lewis, “the first action of the board was to appoint an expert Panel on Haemoglobinometry.”

A recent review article on the changes in standardization in hematology over the past 40 years observed that a key committee established in 1963 on cytomtery and chaired by Crossland-Taylor included W.H. Coulter together with his medical director A. Richardson Jones (42). It is interesting to note that Wallace Coulter personally served on this committee and at the earliest of times recognized the importance of standardization. Even more striking was the fact that he was the only industrial representative on the initial committee. Subsequently, representatives of Sysmex, Technicon/Bayer, and Abbott were added for balance (42).

There was a time where there were few automated instruments in hematology. However, from the 1950s through the 1970s many companies developed technologies in order to compete for the huge market that had developed as thousands of instruments became established in clinical laboratories. Wallace Coulter and his team continued to develop instruments for the hematology field. This was the core technology of Coulter Electronics and Wallace’s great passion. His instruments became increasingly sophisticated, mostly in response to competition. Wallace always met the completion head on and constantly looked for ways of expanding existing tools to perform new measurements.

Industrial Applications

Wallace was involved in anything that related to particle measurement in the 1950s–60s. His interactions with the Office of Naval Research led to several projects, one of which was linked to deep-sea research. In his video interview Robert Klein (16) states that Coulter provided a unit to the Navy for the purposes of testing particulates in deep-sea dives. The US Navy purchased the Bathyscape Trieste, a deep water bathysphere, from the French Navy in 1958, and Wallace was asked to design a particle counter that could operate at a depth of around 300 meters (16). According to Klein (16) the Coulter counter was also used in the development of Saturn V rocket fuel—testing particulates in that fuel. Clearly Wallace Coulter looked at every possible use of the Coulter counter as yet another challenge.

Even before developing the Coulter principle, Wallace worked on several diverse projects, such as a fully automated sterilizer unit for milk (43) that without doubt gave him a working knowledge about fluid management within a relatively complex system. His interest in designing amplifiers for hifi systems led to another industrial application. The principal goal was to produce high-power, low-noise amplification. To market the amplifiers, Wallace and one of his engineers, Abe Siegelman, had formed a company called “Coultamp” (Coulter-Amp), which was to develop and sell large, clean, valve-based hifi amplifiers. Wallace had the idea of creating a separate line of amplifiers specifically for this growing hifi market; his technology was incredibly clean because he had previously developed these amplifiers specifically for the cardiograph market, an area where low-noise amplifiers would greatly enhance the signal-to-noise ratio, and had produced a number of different models (16). At this point he modified the amplifiers he had already designed for cardiographs to suit audio applications. Wallace recognized that the key need for both markets was good clean signal amplification with very low noise. What Wallace did not count on was the arrival of cheap transistors that for all practical purposes rapidly removed the valve-based amplifier business from the hifi market. Ironically, the transistor was invented in 1947, probably at the very time Wallace was thinking about the various problems that shaped his inventive nature. By the time Wallace was building amplifiers, Texas Instruments had produced the first commercial transistor in 1954 (44), and the low cost, the physically small size, and the low power consumption essentially killed the valve amplifier market for nearly 50 years. Ironically, there exists today a host of audiophiles who long for the very valve amplifiers that Wallace Coulter was making in the 40s and 50s. Regardless, the Coultamp company never survived the onslaught of the transistor, but Wallace used this...
latest technology in his development of the Coulter S instead. Coulter’s very knowledge of how to manufacture low-noise amplifiers was fundamental to his success in designing and manufacturing a set of instruments whose very operation was dependent upon low-noise, high-signal amplification—a data set that was critical to his movement into the hematology field.

Early in the development of the Coulter technology, Wallace understood the importance of accurate particle counting in industry. His earliest attempts at evaluating paint represented a clear opportunity for quality control. Counting small non-biological particles was a time consuming and expensive business in the post-WWII period. The measurement of particles such as sand, grit, dust, and industrial samples involved excessively time-consuming processes of sedimentation—processes that could not be made more efficient without being significantly changed. Detailed discussions of the processes involved and the power of the Coulter methods in industrial settings are identified in Line’s and Allen’s publications (45, 46). In the late 1960s a special model for industrial use, the Model T1, was developed; it was designed with a 15-channel pulse analyzer and up to a 2-mm aperture, allowing size determination of very large particles. This instrument was extensively reviewed by McVave and Jarvis for a wide range of industrial applications (47). A great advantage of the Coulter principle in applications involving a huge range in particle count and size (such as muddy water) was that several different-size apertures could be used to account for different-sized particles, but the principle of measurement remained the same, allowing the process to remain consistent (47). The key advantage, however, was that the time factor for multiple measurements of samples was vastly shorter with the Coulter counter than with any other technology; the entire world of industrial particle counting, from chocolate to paint, was transformed by the aperture principle.

Managing Large Data Sets

Wallace Coulter understood that the increase in the number of parameters that his instruments were able to collect placed a great deal of pressure on management of the data. He also understood that his instruments were actually computational devices first and result deliverers second. Even his very first instrument, the Model A, had to be corrected for low counts, as doublets were counted as only a single cell. Wallace solved this problem by drawing the conversion onto graph paper and providing a curve from which the user manually modified the actual counts. Wallace and his engineers spent a great deal of time trying to remove this calculation step by incorporating the computation into the hardware. It was not easy, but eventually Walter Hogg, the chief engineer, performed this major feat, allowing the transition from manual to fully automated systems. As described by Robert Klein (16) it was Hoag who came up with the algorithm that performed the count conversion, and it was Wallace and his team of electrical engineers (notably Klein) who were able to transform that algorithm into an analog computer and eventually into digital computers. The fundamental result of this feat is perhaps not well understood—indeed, this conversion algorithm, now in hardware, was universal for any aperture size and was transferable across all levels of the Coulter hardware. This success, achieved in the original basement laboratory in Chicago, must have been a major event in the transition of the small company into one with huge potential.

The attention to computing capacity did not stop here. Over the next three decades, Coulter always strove to utilize computer power to reduce the complexity of problems for the user. This is evident in Models B and C, which had power-hungry vacuum tubes all designed to reduce the huge amounts of data collected by the electronics to simple, accurate numbers.

Laboratory information-management systems (LIMS) are routine components of both research and clinical laboratories today. Wallace Coulter was one of those who pioneered early forms of LIMS in the early 1970s with the Particle Technologies operations. All the instruments built initially required PDP 8 or 11 computers, Tektronix data stations, and some kind of print output. Linking data between instruments was not even a consideration in those days; individual instruments needed all the computing power available just to operate. Hematology and pathology laboratories were not automated in any way in terms of data management. The majority of data output was the printout—and even obtaining copies of graphics was difficult as there were few ways to transfer graphics to paper.

Wallace Coulter was able to see the future of laboratories linked by computer systems; his foresight was based on the sheer necessity to solve the problems of the increasingly large data-set sizes for instruments such as flow cytometers and image-based systems under development, such as the Diff4, and the need to record data sets for entry into patient medical records.

Wallace’s foresight in the area of computers in technology placed him several years ahead of others. As the technologies he was developing became increasingly available, he reasoned that it was just a matter of time before these tools would be linked and results integrated into database systems that had the capacity to bring together a huge amount of data.

Conclusions

Wallace Coulter was not a confrontational, “do it my way” person. Instead, he actually did it his way himself and led by example. He was an engineer first, when he needed to be inventive. He was a businessman first, when he needed to win the commercial war. However, he was a highly determined individual who was not prepared to accept second place in anything he did. At no time in his career did he make himself an example of greed, corruption, or power. Instead he operated in a quiet, effective fashion by showing his employees the best way to achieve great goals. He treated his employees like his own family and routinely “fixed” problems for his employees when they needed help. Above all, Wallace Coulter knew that the success of his company lay somewhere in between the inventions and the sales. He knew that at all times he had to...
maintain outstanding research and development groups. Wallace Coulter recognized the necessity of maintaining absolute state-of-the-art leadership if one is going to operate in high-technology areas. While he surely made errors of judgment and sometimes placed bets on technologies that did not succeed, he never let those consume him, nor did he fail to re-capture a technology he had previously dismissed or to dump a technology that did not fulfill his hopes for success, if either was necessary.

Wallace Coulter was compassionate about his employees but was equally aggressive against his competitors, knowing that in the end, sales counted. There are countless stories told...
by employees who were practicing sales pitches that Wallace would intervene and explain how to get the message to the customer. To Wallace Coulter, the customer was always right. Even when he was far less active in managing the company, time after time he would step in where he thought his leadership was needed. His transition from a basement where every instrument was hand built to a large manufacturing operation distributing hundreds of thousands of instruments did not happen by chance. It was driven by an engineer who thought of himself more as someone doing the people’s works—looking at the problems facing humanity and trying to solve them one at a time. The tools and technologies developed under the leadership of Wallace Coulter were transformational in the 1950s and 1960s, and by the 1990s had become routine for their time (Fig. 10). It has been said that 97% of all hematology counters are of technologies pioneered by Wallace Coulter. It is simply not possible to look at Wallace Coulter’s life work and derivations of technologies without wondering what it would be like today had he not spent those several years sitting in his basement playing with capillary tubes, foil, needles, and amplifiers. His goals of quantification but simplicity, speed but accuracy, and inexpensiveness yet quality were virtues he maintained and used to drive his commercial ambitions. He created an instrument technology that changed the way medical diagnosis is done, and the tests that he created, while the most common and most often performed of all medical tests today, are also many of the cheapest and fastest in the diagnostic domain. Coulter’s desire was always to address issues of the common man—he saw poverty and sickness and he wanted to utilize his engineering talents to impact, as much as he could, the quality of life of ordinary people. Wallace Coulter was not just an engineer—he was the People’s Engineer.

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