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## Introduction

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In any society, professional or otherwise, certain individuals stand out by virtue of their ability, leadership qualities, other personal attributes, or combinations thereof. Mack Fulwyler had all of these but somehow even more. His philosophy of life, revealed in the manner with which he dealt with others, reminded one of Henry Thoreau with respect to the grandeur of nature, Thomas Edison with respect to the virtues of persistence and ingenuity, and Walt Whitman with respect to the freedom of thought and spirit.

Mack Fulwyler the inventor made fundamental contributions to numerous fields of science and technology, and Mack the individual enriched our lives by being a superb friend and mentor. In this special issue of *Cytometry*, his colleagues acknowledge their debt and appreciation with

scientific contributions closely linked to Mack's work—in two cases, representing some of his own unpublished investigations—and with personal reminiscences about their interactions with him.

We are very thankful for the opportunity to offer a unique tribute to a towering figure in the field of analytical cytometry and hope that this memorial issue will serve as an inspiration to younger students and practicing scientists. In addition, we recognize not only the memory of Mack Fulwyler but also the living presence of his wife, Carol, unflagging partner through the many successes and vicissitudes that marked Mack's career.

**Thomas M. Jovin and János Szöllösi**

## Mack Jett Fulwyler, Pioneer of Flow Cytometry and Flow Sorting (1936–2001)

**L. Scott Cram<sup>1</sup> and Donna Arndt-Jovin<sup>2</sup>**

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Mack Fulwyler conceived of and built the first flow sorter and is thus recognized as the pioneer of the field. Based on this and his numerous other innovative contributions to flow and imaging cytometry and cell biology, this issue of *Cytometry* is dedicated to his achievements and memory.

Up to the time of his untimely death he was pursuing a number of projects in collaboration with scientists around the world and starting a new research group as a professor at the University of South Florida. His most recent contributions were in the areas of photochemical polymerization, photoactivation, photochromic conversion, FRET measurements, bead-based assays, cell membrane studies, single-molecule detection, and capillary array analysis. These and related areas of research constitute the subject of this special commemorative issue of *Cytometry*. Mack Fulwyler's personality and influence were felt by hundreds of collaborators and coworkers with whom he interacted. Some of these many individuals have shared their thoughts (see below) regarding Mack's technical contributions and his warm and caring personality.

Mack Fulwyler was born on July 6, 1936 in Nampa, Idaho. He received his B.S. in Physics from Idaho State College in 1961. After serving with the U.S. Army Chemical Corps he joined the staff at Los Alamos Scientific Laboratory. His earliest work at Los Alamos was in collaboration with Marv Van Dilla on isotope metabolism and monitoring radioactive fallout levels in humans. This work contrib-

uted to our current understanding of iodine binding in the thyroid. In 1964, while continuing his work with Van Dilla, he conceived of and built the first droplet flow sorter (1–3). At the same time the group implemented optical detection of cellular DNA staining using the fluorescent Feulgen staining and determination of cell volume by light scattering (4–6). Mack's pioneering work led to the completion of his doctorate at the University of Colorado Medical School in 1968, where he worked with Theodore (Ted) Puck. After returning to Los Alamos he was principal investigator on an early National Cancer Institute project to automate detection of cervical cancer using flow cytometry and cell sorting. In 1971 he left the Los Alamos Laboratory to become president and CEO of Particle Technology, a start-up company funded by Coulter Electronics. Here he developed one of the early commercial flow cytometers and developed new techniques for production of uniform microspheres for use as standards. His work spurred active commercial development—continuing to this day—of which Mack was one of the pioneers.

He received the prestigious Senior Scientist Research Award of the Alexander von Humboldt Foundation in 1976–1977 to work at the Max-Planck Institute for Biophy-

sical Chemistry in Göttingen, Germany, on the development of a technique to orient biological cells in flow-through analysis and sorting systems. During his tenure there he also developed a rapid micromixing device capable of measuring fast chemical reaction rates.

From 1977 to 1982 Mack was technical director at Becton Dickinson FACS Systems. He was responsible for developing research applications of flow cytometry, predicting clinical uses of the technology, and the development of instrumentation and reagent systems for research and eventual clinical use. He oversaw the development of the Research Analyzer, Becton Dickinson's first bench top flow cytometer and predecessor to the FACSCAN, the FACS Calibur and LSR.

As the field matured Mack turned to academia (1982–1990) and assumed the position of Director of the Laboratory for Cell Analysis at the University of California, San Francisco. He returned to Europe as a Fulbright scholar in 1998–1999 to work with Tom Jovin in Göttingen and Sándor Damjanovich at the Medical University in Debrecen, Hungary. Mack had collaborated with both groups since 1976, when they all met in Göttingen in Tom Jovin's lab. Mack was credited with the founding of two companies. At Neocrin he was Director of Technical Development (1990–1994) and worked on the encapsulation of islet cells. Mack also worked for several years (1994–1997) on rapid DNA sequencing at SEQ Ltd. in Princeton, New Jersey, where he was Vice President for Research and Development.

Mack was always committed to dissemination of information and was pleased to be invited by the Smithsonian Institution in Washington, D.C. to advise them on a display of a cell sorter (1988) and to take part in the Smithsonian Video History of Scientific Developments (1991) that included the cell sorter. Mack Fulwyler was awarded more than 15 patents for his inventions in flow cytometry and sorting and published numerous peer-reviewed articles in

the literature. He was a charter member of ISAC, a councilor on the first ISAC council, and a member of the first ISAC Editorial Policy Committee. In 1994, he was the recipient of the ISAC Distinguished Service Award. He served on the National Institutes of Health Committee on Cytology Automation and was a member of the editorial board of the *Biophysical Society Journal*. In 1976 he was Chairman of the Engineering Foundation Conference on Automated Cytology.

As noted below, his friends and colleagues remember him as a warm and generous mentor who shared his innovative ideas with others and stimulated them to render concepts into reality. But Mack was also a lover of nature, a fanatic and accomplished fisherman, a faithful friend, and dedicated husband and father.

*ISAC leadership and membership have, in acknowledgment of Mack Fulwyler's singular contributions and achievements, established a Memorial Award in his name. Memorial donations may be sent to the International Society of Analytical Cytology, Mack Fulwyler Endowment Fund, c/o ISAC, P.O. Box 71495, Chicago, IL 60694-1495, USA. Those interested in making a donation are asked to ascertain if their employer will match donations from their employees.*

1. Fulwyler MJ. Electronic separation of biological cells by volume. *Science* 1965;150:910–911.
2. Fulwyler MJ. Particle separator (the deflected droplet cell sorter). US Patent 3,380,584; 30 April 1968.
3. Fulwyler MJ, Glascock, RB, Hiebert, RD, Johnson NM. Device which separates minute particles according to electronically sensed volume. *Rev Sci Instr* 1969;40:42–48.
4. Van Dilla MA, Mullaney PF, Coulter JR. Health division annual report (July 1966–June 1967). Los Alamos: Los Alamos Scientific Laboratory; 1967.
5. Van Dilla MA, Trujillo TT, Mullaney P, Coulter JR. Cell microfluorometry: a new method for the rapid measurement of biological cells stained with fluorescent dyes. *Science* 1969;163:1213–1214.
6. Mullaney PF, Van Dilla MA, Coulter JR, Dean PN. A light scattering photometer for rapid volume determination. *Rev Sci Instr* 1969;40:1029–1032.

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## Personal Remembrances

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On Mack's bookshelves are a myriad of scientific and technological books and magazines as well as Feynman, Hawking, Patrick O'Brian, Bloom County, Woodworking, Hoover Digests, Fly Fishing in Salt Waters, and many more that kept him company. Belatedly, he wanted to read all of Steinbeck, all of Hemingway. The written word was a gold mine to Mack, who enjoyed using words as well as saying some just because they rolled off his tongue with delight and sounded good to the ear: Don Quixote de la Mancha, mon petit chere, circuitously . . .

I saw Mack ski well, hike strongly and challenged skillfully by four-wheel eco-driving. A catch-and-release man, he fished with friends for the enjoyment of being with them and for the pleasure of being outdoors. Thinking it was the Cherokee in him, we often vacationed in places where a

compass or GPS was a necessity; he enjoyed the unknown in many aspects of his life. Off and on, we vacationed with ISAC friends: laughed until we were silly, got lost, ate well, talked ideas, attended concerts . . . Always "pushing me ahead," he was pleased he was secretary/treasurer, and proud I was president of our San Francisco business adventure. Truly, it should have been the reverse! "Brainstorming," a beneficial tool for Mack, his get-it-done attitude and his mental generosity carried over into our business and our personal lives . . . Because time was a gift to Mack, he used it most efficiently: when he gave his watch to his son, I absolutely knew that he knew he had lost the battle for life. Mack felt subordinate to a few of his genius colleagues but never felt superior to any, and he understood the importance of others. He played cribbage with zeal, danced with joy and

wanted to return to life as a Greek because of their deep passion for living. So, look for this superlative man, extraordinary physicist, and half my heart when you're having your morning coffee in Greece.

**Carol H. Fulwyler**  
Sarasota, Florida

In a life of no little personal chaos that he often could not change, Mack's interest in science and technology was a refuge where he could control, create and contribute, as he did with great success. Although he was out of touch with most of his family once he left Los Alamos, he was a good father when his children were small. Dad encouraged curiosity and questions and he shared his love of the outdoors. I remember hiking, camping and fishing trips, exploring tide pools in California, The Field Museum in Chicago, and concerts at the Denver Symphony. His passion for science left me with a profound appreciation of logic, technology, and nature.

Humor helped my father deal with life and, later, with death. I was able to spend days with Dad just before he died. It was both sad and wonderful to find that his giggle was the same as I remembered and that his humor survived, even in a most difficult situation. We laughed while speculating on an afterlife. After that, Dad gave me his watch to give to my brother, Rick. I think it was Dad's way of acknowledging his impending death and of expressing his appreciation and admiration for his son who had spent time trying to help in the last, very difficult weeks. Dad's family still reminisces about when Dad used to visit, about what fun it was to have an internationally known scientist who made important contributions to the diagnoses and treatment of major diseases (one of which he suffered from—diabetes), and giggling happily when in the silly company of his brothers. Humor and science—a worthwhile combination and a contribution to life.

**Connie Jo Fulwyler**  
Albuquerque, New Mexico

I loved my father. I remember him as being gentle and kind. I loved to hear him laugh. When I was about 10 years old, I remember being proud of the fact that I was the only kid on the block with a laser in his garage! My parents separated when I was young. I did not see my father often after I graduated from high school. I have fond childhood memories of him and the time that we spent together. He took my brother and me fishing, hunting, and backpacking. When I was 18 years old, Dad took me with him on a business trip to Western Europe for 3 weeks. I loved spending that time with him and appreciated the opportunity he gave me to explore other countries and cultures. That was a great gift. When Dad was dying of cancer I was able to spend the last 3 weeks of his life with him and his wife Carol. I'm grateful that I was able to spend that time with him. We got to know each other a little better. I loved him very much and wish that we could have spent more time together. Often I will be engaged in an activity such as hunting fossils or wild mushrooms and wish that he

could be there. I loved him very much and miss him. I'm proud of him for all his professional accomplishments.

**Richard (Rick) Mack Fulwyler**  
Albuquerque, New Mexico

Not only did Mack Fulwyler make major contributions to science and academia, but he was also a kind and affectionate man with a ready smile and a whimsical sense of humor. I remember many silly, noncerebral laughs over a cribbage board or on a fly fishing trip. His personal life, like most, may not have been wrinkle free, but I feel he overcame issues admirably, and any discrepancies in his perceived roles are easily outweighed by his contributions to science and the world at large. He remained driven and ambitious to the end. As if he had not accomplished enough in his all too brief lifetime. I have always been endlessly proud of him. He is the reason I chose science as a career. His are big shoes to fill.

**James Brent Fulwyler, youngest son**  
Los Alamos, New Mexico

Mack was a true innovator, a person who bestowed on biologists a new vision and a new tool that radically altered the fields of clinical and developmental immunology and tumor and cell biology. But in addition to his prodigious talents as an instrument developer, Mack developed strong interests for the underlying biological problems and contributed new ideas and fresh approaches in a variety of disciplines. He was able to do this by virtue of being an open, warm individual, a good listener, but who also spoke with authority. We remember Mack for the sunshine in his eyes and voice. He cared deeply for all the individuals with whom he associated in a personal, supportive, but unobtrusive way. We shared many happy hours with him inside and outside the lab during the times of our collaborations. That is, he treasured his friends and they (we) treasured him. Although we lived on different continents, Mack was always ready for spontaneous activities, e.g., picking up for a walk on the beach when we just happened to be traveling through. His love of nature, hiking, camping, and fishing was legendary. But he adjusted his stride to those around him, as we remember particularly from a wonderful trip in the Sierras with him and Carol and our young, inexperienced hiker daughters. We dearly miss this extraordinary friend and colleague and pay tribute to his scientific legacy in this special issue of *Cytometry*.

**Donna Arndt-Jovin and Tom Jovin**  
Max Planck Institute for Biophysical Chemistry  
Göttingen, Germany

"Just imagine this"; with those words Mack would often share his solution to a problem that he was thinking about. Mack loved to solve difficult technical problems and always strove towards solutions that were elegant in their simplicity. He would solicit critical feedback to improve those solutions. Mack encouraged all of his employees to function in this manner. I had the privilege

and pleasure of working with and learning from Mack at Particle Technology from September of 1973 through January of 1976. I consider that the most enjoyable and productive work experience that I have had in my life. When circumstances caused us to take different paths and even become competitors, we remained friends. Every so often I would get a call out of the blue and the voice on the line would say: "just imagine this." We would discuss his latest idea. Mack was a scientist and a teacher, but most of all he was a gentleman.

**Bob Auer**

Key Largo, Florida

I was Mack's first employee when he founded the Lab for Cell Analysis at UCSF in 1982. He was extremely supportive of my growth in the field and allowed me to make many mistakes as I learned. He was very much a do-it-yourselfer and tinkerer. From Mack I also learned how one copes with difficulties; he was diabetic and had to deal with the consequences of his condition on a day-to-day basis. He did not try to hide anything and was forthright about its effects. This has been a good lesson for me as I have had to deal with my own infirmaries.

**Marty Bigos**

Gladstone Institute  
San Francisco, California

Mack Fulwyler was a dear friend, mentor, and colleague. We first met in 1968 when Mack and Marv Van Dilla showed me their flow cytometer. After moving to Los Alamos in 1969, our families became close and we enjoyed many social occasions together. One evening, just after he formed Particle Technology, Mack asked me if flow cytometry would be a successful commercial enterprise. After my enthusiastic endorsement, Mack described his vision, a vision that included ideas that are just now, 35 years later, being pursued as well as ideas that still remain to be developed. Mack was adept at conceptualizing ideas that reached well beyond the technology of his time. Although quiet and reflective, he never hesitated to help and encourage others and particularly new investigators. He loved the out of doors. He was an avid fisherman and target shooter who enjoyed fabricating fishing rods and loading his own ammunition. Mack had an intuitive sense about how things worked—he often repaired automotive components that he knew nothing about before starting. He was known for being able to simplify equipment design. Mack would say "let's make it work better and be user friendly." I admired Mack, enjoyed his company, and greatly benefited from his insight. Mack was disciplined and dedicated. He was so personable, just a wonderful person, and one who made incredible contributions to human well-being.

**Scott Cram**

Los Alamos National Laboratory (retired)  
Tucson, Arizona (current)

Mack had a very warm personality, but he needed time to start a real friendship. He had a quiet and very modest per-

sonality. He was an unselfish and an unforgettable friend. He, Asher Porath from the Hebrew University of Israel, and I were acquainted and started our friendship in Göttingen in 1976, which lasted until his unfortunate departure. We were really shocked when, not long after returning to the United States from Hungary, he was mercilessly destroyed by a cruel disease. We will never forget him.

**Sándor Damjanovich**

University of Debrecen  
Debrecen, Hungary

My memories of Mack Fulwyler as a friend and scientist of exceptional accomplishment began in the early 1970s. By the time I met Mack, he had already invented cell sorting at Los Alamos and left there to form Particle Technology with the goal of making the technology available to the general scientific community. Mack's enthusiasm for innovation coupled with early transfer to the private sector for public dissemination remained a constant theme throughout his life. Pursuing these twin loves led Mack to found Particle Technology and then to Becton Dickinson where he helped to make this a robust technology for the scientific community. Mack left Becton Dickinson to join the University of California, San Francisco, where he started the Laboratory of Cell Analysis, which continues to this day in making technologies that Mack pioneered available to the scientific community. I followed Mack at UCSF when he moved on to pioneer new fields including aspects of pancreatic islet isolation and encapsulation needed in diabetes research and then to explore the merits of single-molecule DNA sequencing.

I kept track of Mack during his decades-long career thanks to periodic fishing trips to Alaska, Montana, Idaho, New Mexico, and the Bahamas. My last fishing adventure with Mack was to South Andros Island in the Bahamas for a few days of bone fishing. The fishing and informal science discussions were great. Evidence for the latter is a U.S. patent that was conceived in the back of a pickup truck during a long ride from the boat to the "hotel." In short, I remember Mack as a scientist, friend, sportsman, and gentleman. I miss his good humor and keen scientific insights.

**Joe Gray**

Lawrence Berkeley National Laboratory  
Berkeley, California

In 1967 I went to visit Mack and spent two momentous days with him at Los Alamos. He had built a flow sorter based on Coulter particle volume. He took this to work on biological cells at the University of Colorado, with Ted Puck demonstrating the first cell flow sorter. On that visit, I asked Mack and Marv Van Dilla if they would add fluorescence to Mack's volume sorter. They both said fluorescence was not in their mission, which was to detect particles of fallout from atomic testing clouds that were in the lungs of rats or mice sent up to breathe in this dust. After a day and a half of talking, which I hoped would convince them that fluorescence would be biologically important and that they had the engineering capability to add it, Mack concluded our discussion by offering generously to give me the detailed plans of his

volume sorter, which I could take back to Stanford and get engineers there to build and then add fluorescence. Well I took his generous offer, got Bill Bonner and others engineers to do just that and built what we later called a fluorescence-activated cell sorter (FACS). A few years later on I encouraged Bernie Shoor to ask Mack to join Becton Dickinson in California. There, I remember his participation in discussions from which many very useful suggestions flowed. It is a regret that he didn't live to fully enjoy how flow cytometry, his intellectual baby, has contributed to so many areas of biology and medicine.

**Len Herzenberg**  
Stanford, California

In 1985, I set off for California determined to learn surfing before heading back to school and the "real world" of the east coast. Through a series of fortunate events I landed in the Laboratory for Cell Analysis (LCA) at the University of California, San Francisco. I thought the LCA was a bizarre name for a cell biology lab with no wet bench located in a funky brick building near San Francisco's Mission District. Mack, with help from Marty Bigos and fueled by neighborhood burritos, turned me on. Working for Mack changed my professional life and set me on a course of learning and discovery that he inspired and for which I will always be grateful.

Diabetes was part of Mack's life and he attacked his disease as a trained physicist. In the strange symbiosis between brilliant people and their afflictions, diabetes was an enemy to be defeated and a source of inspiration for a torrent of wonderful ideas. Together we worked on building large particle or pancreatic islet cell sorters, construction of intricate laminar flow devices for encapsulating transplantable islets, and redesigning confocal microscopes to isolate responding islets by calcium flux. We chased Mack's innovative ideas for isolating islets on slides using UV cross-linking polymers, multisized beads for multiplex identification of secreted proteins and sugars in serum, mounting objectives on the end of optical fibers for in vivo imaging, and the use of AOM devices for controlling laser light in FRAP and FRET experiments. Mack used his unique knowledge of fluidics, optics, electronics, computer science, probe technology, mathematics, and chemistry to find solutions.

Mack invented droplet cell sorting and helped foster the field of cytometry, yet my fondest memory and I believe one of his greatest technical feats was when we replaced the engine in Carol's old Honda. I remember the joy and champagne when we drove the refurbished Honda down the street. Whether it was fixing sorters, building confocals, or replacing engines, each project was tackled with Mack special combination of patience and thoughtful analysis. I must have caused no end of Mack's hair loss, blowing up mercury arc lamps in his FACS analyzer, flooding an argon laser after defeating the interlock (I had help on this one from János Szöllösi), twice flooding a UCSF dean's office a floor below after forgetting to turn off the laser cooling pump on a Friday night, burning a small hole in a sorter wall and igniting the wallpaper in the room next door, and breaking off the heads of special engine mount screws by over torquing. My lesson from Mack

was to always see setbacks as a challenge and to temper success with caution . . . and to do so with humor and grace.

**Bill Hyun**  
Laboratory for Cell Analysis  
University of California, San Francisco

My encounters with Mack spanned a period longer than 30 years and are an example of the old adage that it's a small world. Not knowing one another, we sat next to each other at the commencement ceremonies in May 1969 at the University of Colorado in Boulder. He received his Ph.D. in biophysics for the sorter development and I received mine in nuclear physics for gamma ray spectroscopy. We had a pleasant chat during and after the ceremonies and, of course, my parents were interested in his middle name. At the time I did not expect our paths to ever cross again.

Subsequently my family and I moved to Los Alamos but it would be several years before I entered the wonderful world of flow cytometry. Over the succeeding years, our paths crossed numerous times when we discussed subjects ranging from large particle sorting to DNA sequencing by single-molecule detection. My conversations with Mack, whether they were in a coffee shop in Cambridge with Bernie Shoor or in a small restaurant in New Mexico, were always stimulating and thought provoking. Mack was always a good listener, an astute questioner, and a good friend.

**Jim Jett**  
Los Alamos National Laboratory  
Los Alamos, New Mexico

I met Mack on several occasions but did not develop a close association. However, he was one of the panel members invited by the American Cancer Society, Florida, to review our application for building and testing a flow cytometer for the space station. Mack along with Howard Shapiro and Bruce Bagwell reviewed the application and recommended funding. Dr. David Robinson and I were coinvestigators and with those funds we revived the earlier moth-balled NASA project and built the first NPE flow cytometer as described in *Cytometry*. The NPE system has been improved and is now marketed by Beckman Coulter as the Quest Flow Analyzer. I think his foresight in recommending funding of this project is responsible for the inclusion of volume analysis for high-resolution flow cytometry.

**Atwar Krishan**  
Miami, Florida

I first met Mack Fulwyler when, as chair of the Department of Laboratory Medicine at UCSF, I was attempting to obtain the necessary resources to create a "Laboratory for Cell Analysis" as a shared facility for our campus. Our attempt was at a time when the university was cutting programs, and although this forward thinking idea did finally develop traction at the president's office, it was clear that we would need to find an individual to direct the facility who could be creative in utilizing the less than optimal funding that we would receive. On the recommendation of a number of individuals, including Joe Gray and Bernie Shoor,

we interviewed Mack. I asked him to create a budget for renovating space, for equipping the lab, and for hiring personnel as part of our interchange. His estimates were far lower than those generated by others who had interest in the position. A bit leery of this low bid, I pressed Mack to see how he planned to accomplish the task. He explained how he would work with the contractor to minimize costs by providing design plans and alternative solutions to expensive construction, that he would use his myriad connections to obtain equipment that he could update, and that he would provide much of the maintenance. In fact, his extraordinary skills allowed him to accomplish all of the above. His personal characteristics were such that he joyfully and unselfishly provided expertise to others so that they could accomplish their research goals. Mack delighted in his work and delighted in his play. He was a complicated yet simple person. What you saw was what you got, and it was wonderful. I valued his friendship and his council, and I miss him.

**Larry Marton**

SLIL Biomedical Corporation  
Monona, Wisconsin

I met Mack in late 1982 while working under the direction of Dan Stites, M.D., at UCSE. I was charged with developing and implementing new diagnostic assays, and with Mack's assistance we began to evaluate the use of flow cytometry. Mack's broad range of interests and enthusiasm helped us progress with a variety of applications. Mack and I shared an interest in working with microsphere-based assays and we worked on another of Mack's interests, the development of a macroscopic agglutination assay using colored microspheres. I was surprised to find that Mack and I shared another interest, that of B-western movies, notably those with Lash LaRue, King of the Bullwhip. He, of course, was easy to work with, energetic, and supportive.

**Thomas McHugh**

University of California  
San Francisco Medical Center

To me, Mack Fulwyler was the quintessential engineer and I think about how his approach to cytometry and my own came together from two very different standpoints. Mack was one of the small band of engineers who was able to work with biologists and pathologists in an extraordinary example of interdisciplinary science. His visit to our laboratory shortly after publishing a description of the electrostatic cell sorter remains in my memory as a landmark achievement and his contributions to cytometry helped bring this technology into the essential clinical and research laboratory instrument that it is today. We shall miss him.

**Myron Melamed**

New York Medical College  
Valhalla, New York

I met Mac Fulwyler for the first time at the Elmau Conference organized by Tom Jovin in the mid-1970s. Mack was behind the pioneering development of laser-based flow cyto-

metry at Los Alamos. Because I had worked with Torbjörn Caspersen at the Karolinska Institute on fluorescence microspectrometry, we had a lot to talk about. I was already deeply involved in fluorescence correlation spectroscopy, which at that time was not yet at the single-molecule level. Mack's work in Los Alamos was important for Richard Keller's time-gated single-molecule detection, which was based on the flow system developed by Mack. Dick Keller's work on single-molecule DNA sequencing stimulated a whole field and was also behind the formation of the ATCG Company, later on called SEQ, by Kevin Ulmer. I met Mack again at SEQ in Princeton, New Jersey, where he had an important role in the development of SEQ's effort to sequence single DNA molecules. I always appreciated meeting Mack and the thorough discussions I had with him. Our scientific community has lost a pioneer and wonderful colleague.

**Rudolf Rigler**

Karolinska Institute  
Stockholm, Sweden

I met Mack Fulwyler at a meeting in Chicago in 1968, which was attended by almost everybody then working in flow and image cytometry; he was itching to get back to Los Alamos and play with the newly acquired argon ion laser, which would be used to make multiparameter fluorescence measurements of cells in flow—a radical concept at the time—and his enthusiasm was contagious. Over the years, I was to find that this was pretty much standard operating procedure for Mack; he was quick to move into new areas and always eager to learn as much as he could about them, and pass the knowledge on. The cell sorter was his obvious legacy to the world, but those of us who knew him have many reasons to miss him.

**Howard Shapiro**

The Center for Microbial Cytometry  
West Newton, Massachusetts

I met Mack at a number of ISAC meetings and had developed a great respect for him. When I heard that Coulter was going to close Particle Technology, I thought he would be a great addition to the Becton Dickinson Monoclonal Center in California. The legal department at BD felt it might be a problem for Mack to start to work for BD immediately. Mack told us he could go to the Max Planck Institute on a Von Humboldt fellowship and work with the Jovins for about a year. When his work there was completed, he came to work for BD. He was a very creative scientist and made many contributions. Working with Mack was fun and productive. My wife and I also enjoyed the friendship we developed with Mack and Carol. We miss him very much.

**Bernie Shoor**

Becton Dickinson (retired)

Upon receiving my Ph.D. (1970) I accepted a postdoctoral position at Los Alamos, where I was fortunate of having the opportunity to work under the guidance of Mack Fulwyler. Mack was a great resource for advancing my knowledge in the high-speed analysis and sorting of cells.

During the time that I worked with him I first learned the principles of high-speed droplet cell sorting by using a sorter that he had constructed for separating cells based on differences in size using the electronic cell-volume sensing technique (Coulter principle). Mack and I with assistance from Jim Coulter, Marvin Van Dilla and Paul Mullaney set out to develop a multiparameter flow sorter based on electronic cell size, two-color fluorescence, and light scatter measurements. This first of its kind multiparameter flow sorter (patented) paved the way for a contract with the NCI to develop automation of cervical cancer screening by flow cytometry, with Mack as the principal investigator. To this day I still reminisce on the excellent guidance and supervision provided by Mack Fulwyler.

**John Steinkamp**

Los Alamos National Laboratory (retired)

I guess my most vivid memory of Mack was when I was a graduate student in the late 1970s. I met Mack at my first SAC meeting at Asilomar. What struck me was that, although he was clearly a pioneer in cytometry, there was never a trace of arrogance. He was always high energy and enthusiastic and spoke to me as a colleague, which made a lasting impression on me. He was a man always dedicated to lifelong learning and he never lost his enthusiasm or thirst for the field of cytometry. I still miss him. His loss was tragic for his family, the field, and for all of us who knew him.

**Lisa Staiano-Coico**

Cornell University  
Ithaca, New York

I first met Mack Fulwyler when he worked at BD in the 1970s. The development of the FACS analyzer there under his direction was a pioneering step in the development of small, practical flow cytometers that eventually had important clinical applications. After I did a sabbatical with Elbert Branscomb in Ron Jensen's group at LLL, I returned to the Department of Laboratory Medicine at UCSF, where Mack was eventually recruited to direct the Laboratory for Cell Analysis. It was the vision of our then chair, Dr. Larry Marton, to create the laboratory and recruit the very best person as director. Mack and I formed a firm scientific and personal relationship. We collaborated on a large variety of projects involving immunology, particularly T-cell subset quantitation in HIV-AIDS, and multiple other clinical applications of flow cytometry. The improvements that Mack introduced into flow technology and brought to the clinical laboratory were nothing short of revolutionary. I can say that his friendship to me substantially changed the whole direction of my scientific and medical career. Mack was a solid scientist, a great technical resource, and a quiet and loyal friend. He will be greatly missed but certainly not forgotten.

**Daniel Stites**

University of California San Francisco  
San Francisco, California

My first encounter with Mack Fulwyler was in our laboratory at Stanford University in August 1964. He had

written to me a few weeks earlier, inquiring about my ink-jet oscillograph and, after exchanging a couple of letters and a phone call, he proposed that we meet to "discuss a possible application." That meeting was my introduction to Mack Fulwyler and to biologic cells and cytometry. It was a memorable event in my life. Mack's enthusiasm for his work was evident and I learned a lot that afternoon about Coulter counters, cell and particle suspensions, and the usefulness of providing a method for rapid one-by-one sorting of a mixture of suspended particles into separate classes. He had a knack for explaining novel ideas and his description of his proposed particle sorter intrigued and impressed me. We parted with my best wishes for success and the loan of an "ink-drop gun" from our project. We corresponded a few times over the next 2 years and I learned that he was sorting cells in April 1965 and that in February 1966, Len Herzenberg had started a cell sorter project at the Stanford Medical Center based on Mack's work.

I joined Len Herzenberg's FACS group at Stanford in February 1971 (after leaving Stanford for 4 years at Varian Associates) and had more interactions with Mack at Los Alamos and at ISAC meetings. I didn't really get to know him until after he moved in 1977 to the San Francisco Bay Area and joined Becton Dickinson in Santa Clara. Our lab was then collaborating with BD, and Mack and I met frequently to discuss our projects and to exchange ideas. We became good friends. I marveled at his ingenuity, creativity, and his enthusiasm and delight in everything he encountered. He was a very caring person and was always generous and unselfish with help and support, both professionally and personally.

**Richard Sweet**

Stanford University (retired)

I became acquainted with Mack in 1985 when I was visited his laboratory at the University of California, San Francisco (UCSF), with support from a joint grant from the National Science Foundation and Hungarian Academy of Sciences awarded to Mack Fulwyler and Sándor Damjanovich. This was my first visit to the USA—Mack and Carol helped me in so many ways. Mack met me at the airport, booked a room for me, and invited me over many times. During my stay Mack and Carol visited Hungary (using the same exchange grant) and I had a chance to stay in their home, house sitting, while they were in Hungary, and I was even able to use his Honda. Since 1985 I visited UCSF almost every year. I learned a lot from Mack while working in his laboratory: how to attack various scientific and technical problems, how to write scientific papers, and how to ask and address important questions. Our scientific collaborations resulted in six coauthored manuscripts.

I returned often to UCSF even after Mack left; however, I never lost contact with him. I was especially pleased when Mack visited Hungary in 1999 as a Fulbright fellow and spent half a year at our university. While he was here I organized an ISAC-sponsored international conference entitled "Future Trends in Quantitative Cytology For Clinical and Research Applications" in Hortobágy, Hungary.

Mack delivered the opening lecture of the conference. He gave an eloquent historical perspective about flow cytometry: "When flow cytometry turned the corner." Hortobágy is not so far from Debrecen, in the heart of the Great Hungarian Plain, a place Mack loved and visited often for its beauty and calmness. I was happy to help Mack and Carol while in Debrecen so I could at least partially reciprocate their kindness from when I stayed in San Francisco. I am proud that I knew Mack and gained his friendship. I miss him and will always remember him.

**János Szöllősi**

University of Debrecen  
Debrecen, Hungary

Mack joined the Biomedical Research Group at Los Alamos in the early 1960s to help with an expanding program to apply gamma ray spectroscopy to biological and medical problems. Not long afterward, our group leader, Wright Langham, asked Mack and I to help a pathologist in the group, C. C. Lushbaugh, to extend the capability of the newly invented Coulter red blood cell counter to the measurement of red blood cell size distributions. This got Mack and I into a field new to us, namely high-speed detection of the properties of cells in aqueous suspension. Work on this problem led Mack to the brilliant insight to combine the Coulter counter concept with the principle of electrostatically deflected ink jets developed by Dick Sweet at Varian Corporation as a high-speed oscillograph. The result of this ingenious combination of ideas was Mack's first flow sorter, whereby cells of a particular size could be physically separated out of a mixture containing a variety of cell sizes and at high speed. At the same time, I was developing a flow cytometer to measure fluorescence signals from cells stained with specific fluorescent dyes to mark cellular DNA content. And Paul Mullaney was working on a similar flow system to measure light scattering by cells. Helping us were Jim Coulter, Ted Tru-

jillo, and Phil Dean. These optical flow cytometers proved successful, and Mack was able to incorporate them into flow sorters. This enabled the high-speed analysis and separation of cells in suspension based on electrical (size) and optical signals (including fluorescence, which could be markers for a wide variety of cellular properties). In the succeeding decades applications of these Los Alamos developments resulted in many advances in medical and biological research worldwide. Mack was a key contributor to all of this and deserves special credit for hitting on the unique and imaginative idea of how to achieve high-speed sorting and then having the experimental ingenuity and creativity to actually do it.

**Marv Van Dilla**

Santa Fe, New Mexico

My major memories of Mack center around his love of nature and his willingness to help others. Mack Fulwyler was a true lover of nature. I made several trips to Los Alamos early in my flow cytometry research career. On each visit, Mack would always make sure we had time for a hike or picnic in the mountains or a trip to Bandalier. He loved the country and delighted in showing it to others. His love for nature was contagious. I still cannot travel to New Mexico without taking time to visit the sights Mack first showed me. Mack was exceedingly generous with his time and advice in helping others. I was in the process of building our first slit-scan flow system and, having never built a flow system before, had many questions and issues to discuss. Mack was always willing to spend time with me and provided many useful suggestions. Mack was a valued colleague, and a true friend.

**Leon Wheeless**

The University of Rochester (retired)

Rochester, New York

Charlottesville, Virginia (current)