Dov Jaron and the Origins of Biomedical Engineering

By Alexander B. Magoun

Editor's note: *This month we bring to you an article based on the IEEE Global History Network's Oral Histories series. For the Oral Histories project, IEEE History Center's staff and volunteers have conducted more than 600 interviews, all of which are available on the Center's website, www.ieeeghn.org. Scholars, in a range of fields, have drawn extensively on these interviews as have writers and producers of popular books, articles, exhibits, and documentaries. Some editing has been done, along with the addition of a few illustrations, to make the article more suitable for a journal publication.*

This article covers Dov Jaron's work on the balloon pump and his efforts to increase the visibility of biomedical engineering as a professional field.

In 1999, Rik Nebeker of the History Center interviewed Dov Jaron (Fig. 1), former president of the Engineering in Medicine and Biology Society and now IEEE Life Fellow. The Calhoun Distinguished Professor of Engineering Medicine at Drexel University, Jaron is best known for developing the intra-aortic balloon pump (Fig. 2); building two biomedical engineering programs; and convincing the National Institutes of Health to invest in bioengineering as a complement to research in biology and medicine. Through all of his administrative responsibilities and professional activities, Jaron has continued to publish ongoing research in which he integrates engineering practices, mathematics, and physiological information to correct flaws in the cardiac and circulatory systems. Here he discusses his education; his work on the balloon pump with Adrian Kantrowitz in the 1960s and early 1970s; his program building at the University of Rhode Island and Drexel University in the 1970s and 1980s; and his efforts to increase the visibility of biomedical engineering as a professional field in the 1990s. Professor Jaron's quotations below come from this interview, which is available in full at http://ieeeghn.org/wiki/index.php/Oral-History:Dov_Jaron.

I. FROM PALESTINE TO DENVER, COLORADO, USA

Born in 1935, Dov Jaron grew up in Tel Aviv, Israel, where his parents had emigrated from Lithuania in the late 1920s. After serving two years in the Israeli army and four more at the kibbutz he had been defending, Jaron attended the Technion in Haifa, Israel, for a year before transferring in 1960 to the University of Colorado in Denver, USA, where he majored in electrical engineering. At the time, "[it] was not a high-powered research university, particularly not in engineering," but Jaron attended because some relatives lived nearby.

Coincidentally, however, Freudian psychiatrist Sidney Margolin (1909–1985) was exploring the use of electronic instrumentation in measuring psychophysiological responses at the university's medical center. "He lived in New York for many years and treated some of the most famous movie stars as a psychiatrist, then he decided he had enough of the city life and moved to Denver to be on the faculty. He was an electronics nut." Jaron maintained Margolin's home-built, tube-powered, ECG/EKG machine and the experience, along with his grades, sparked his career path through fellowship offers from all three of the biomedical engineering programs initiated in 1962 by funding from the National Institute of Health.

Biomedical Engineering at the University of Pennsylvania

Jaron chose to go to Philadelphia, where he learned not only from Herman P. Schwan (1915–2005), one of the

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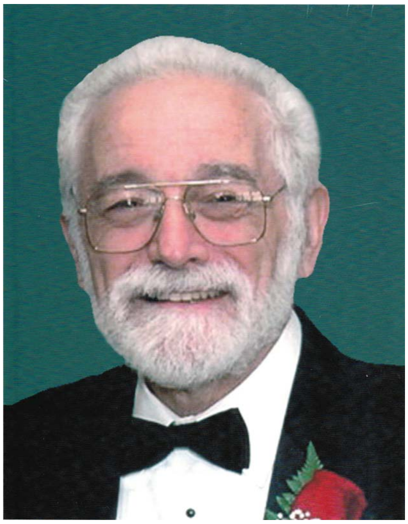

Fig. 1. ***Dov Jaron, shown here at an IEEE honors ceremony.***

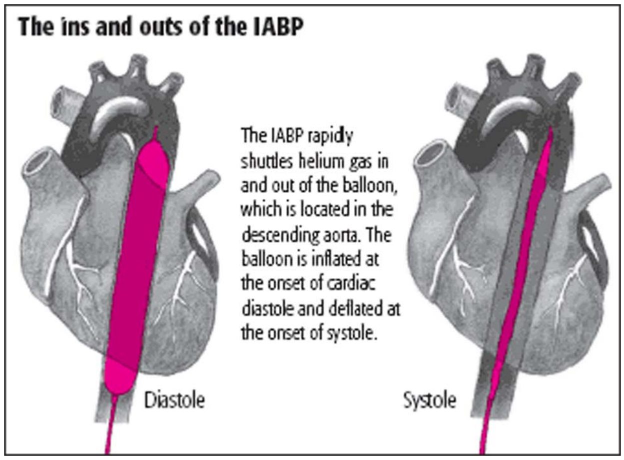

Fig. 2. ***An intra-aortic balloon pump (IABP) is a mechanical device that helps the heart pump blood.***

founders of academic bioengineering,[1] but Samuel Talbot (1903–1967) as well. Talbot started the bioengineering program at Johns Hopkins University, but before he moved to the University of Alabama he "came every two weeks to Pennsylvania and gave the most thought-provoking seminars that I ever experienced. Each student had to do a project, had to read papers. There was a lot of preparation for those seminars .... Some of the luminaries in the field were there. [Herman P.] Schwan was there and David Geselowitz ...."

Working with Schwann, Geselowitz, and cardiologist Stanley Briller, Jaron researched a thesis on cardiac pacemaker electrodes in the mid-1960s. Pacemakers were still a novel, bulky technology with a fixed rate,[2] and no one understood the physical relationship at the interface of electrode and human tissue. Jaron carried out time and frequency domain studies to develop a theoretical model, tested it in the lab using saline models, and finally applied it to patients.[3] In addition, Geselowitz posed the question of whether

> from the surface of the body, can you deduce what happens to the generator representing the heart .... [That] is what electrocardiography is all about. But electrocardiography has serious limitations. He [Geselowitz] was trying to figure out whether there is a better way of getting more information about the generator. With a pacemaker, we knew exactly the properties of those generators. We knew exactly what the current of the pacemaker is, what the voltage is, so we tried to measure surface potentials and relate those surface potentials to the pacemaker as a generator.[4]

Jaron developed an approach to this problem as well and defended his dissertation in spring 1967.[5]

II. OPTIMIZING THE INTRA-AORTIC BALLOON PUMP, 1967–1972

The intra-aortic balloon pump is used by 160 000 patients around the world as a mechanical auxiliary for weakened hearts.[6] The principle, first demonstrated in 1962,[7] is to

[1]See Kenneth R. Foster, "Herman P. Schwan: A Scientist and Pioneer in Biomedical Engineering," University of Pennsylvania ScholarlyCommons Departmental Papers (BE) http://repository.upenn.edu/cgi/viewcontent.cgi?article=1055&context=be_papers, visited 1 December 2014, reprinted from *Annual Review of Biomedical Engineering* 4 (August 2002), especially pp. 20–25.

[2]The most recent historical studies of the pacemaker are Jeffrey Kirk, "Pacing the Heart: Growth and Redefinition of a Medical Technology, 1952–1975," *Technology & Culture* 36, no. 3 (July 1995), pp. 583–624; and Id., *Machines in our Hearts: the Cardiac Pacemaker, the Implantable Defibrillator, and American Health Care* (The Johns Hopkins University Press, 2001).

[3]D. Jaron, S. A. Briller, H. P. Schwan, and D. B. Geselowitz, "Nonlinearity of Cardiac Pacemaker Electrodes," *IEEE Transactions on Biomedical Engineering*, vol. 16, no. 2 pp. 132–138, Apr. 1969.

[4]D. Jaron, H. P. Schwan, and D. B. Geselowitz, "A Mathematical Model for the Polarization Impedance of Cardiac Pacemaker Electrodes," *Med. Biologic. Eng.*, vol. 6, no. 6 pp. 579–594, Nov. 1968.

[5]Dov Jaron, "A Study *In-Vivo* and *In-Vitro* of Electrical Correlates of Artificial Cardiac Pacemakers with Emphasis on Electrode Polarization," Ph.D. dissertation, University of Pennsylvania, USA, 1967.

[6]Patricia Hanlon-Pena and Susan J. Quaal, "Intra-Aortic Balloon Pump Timing: Review of Evidence Supporting Current Practice," *American Journal of Critical Care* 20, no. 4 (July 2011), p. 324, www.aacn.org/wd/Cetests/media/a112004.pdf, visited 1 December 2014.

[7]Spyridon Mouloupolos, Stephen R. Topaz, and Willem J. Kolff, "Diastolic Balloon Pumping (with carbon dioxide) in the Aorta: A Mechanical Assistance to the Failing Circulation," *American Heart Journal* 63 (1962), pp. 669–675. See also "This Week's Citation Classic," *Current Contents* 8 (February 20, 1984), p. 16, http://garfield.library.upenn.edu/classics1984/A1984SB92000001.pdf, visited 1 December 2014; and Stephen R. Topaz, "How the Balloon Pump was Conceived: A Personal Reminiscence," *Cardiovascular Diseases* (Bulletin of the Texas Heart Institute) 4, no. 4 (1977), p. 423–427, www.ncbi.nlm.nih.gov/pmc/articles/PMC287689/?page=1, visited 1 December 2014.

insert a balloon in the descending thoracic aorta and synchronize it with the heart so that when

> the heart begins to pump blood, to eject blood, you deflate the balloon, thereby creating a lower lobe low resistance, making it easier for the heart to pump the blood. When the ejection period of the heart is finished and the aortic valve closes, the balloon is inflated, which displaces the blood to the periphery, but more importantly towards the heart . . . . You are perfusing the heart itself as well as the periphery . . . . increasing the blood supply to the heart, which in the case of a heart attack is a problem; and also increasing the blood supply to the periphery; and reducing the workload on the heart, making it easier for the heart to recover.

One challenge to practical implementation was to optimize its effect by calculating how and when to inflate the balloon. Jaron joined the pioneering and inventive heart surgeon Adrian Kantrowitz (1918–2008)[8] at Maimonides Hospital in Brooklyn, New York, whom he knew for his work on implantable pacemakers.[9] Kantrowitz needed an engineer; he described his pacemaker as "the worst engineering" that collaborating General Electric engineers "had ever seen."[10] With his brother, physicist Arthur Kantrowitz (1913–2008), and a National Institute of Health grant, he had also been developing the intra-aortic balloon pump. Using a Digital Equipment Corporation PDP-15 minicomputer, "not a very good machine," Jaron spent five years developing cardiovascular simulations on punched cards. He and the rest of Kantrowitz's team "actually made the balloons. We made everything, tested it on animals extensively, and then used it on patients."[11]

The greatest challenge was synchronizing the valves for the inflation and deflation cycles through an oscilloscope: "We picked up the signal on the oscilloscope, and then we synchronized the balloon from output of the oscilloscope . . . . [E]ven now it is not automatic. It is much more sophisticated now, but it is not completely automatic.[12] If you have a regular heartbeat, it is fine. But those patients do not have a regular heartbeat."

Potential users still viewed the technique with some suspicion. "We got a call from the family of President [Dwight] Eisenhower to come with our device because he was hospitalized with a bad heart. His physician vetoed it; he did not want us to come." In another early instance,

> [A] physician on a trip to Sicily was hospitalized with a heart attack there, and he was deteriorating very quickly. His son . . . asked us to fly over to Sicily with our equipment . . . . What we did was to organize basically a small hospital and ship it to Sicily . . . . The son had a lot of influence with the Air Force, so he had the Air Force fly compressed helium to Sicily by special jet. We got on a plane in Detroit and flew to New York . . . . The son met us . . . and he said, "You know something, my father is improving. So I am going to save the money." So we turned around and flew back to Detroit. When we landed . . . we got a telephone call that his father had died. It may have been a day later. Had we been there, we might have been able to save him.

III. BUILDING PROGRAMS AT UNIVERSITY OF RHODE ISLAND AND DREXEL UNIVERSITY, 1973–1991

As gratifying as it was to contribute to a device and technique that improved treatment and saved lives, Jaron found that he was less skilled in the marketing that is essential to commercial innovation. He returned to academia through the Electrical Engineering Department at the University of Rhode Island (Fig. 3), which hired him to expand the bioengineering option in EE to its own major. Working with hospitals and medical schools in the state, Jaron built up the program and continued his research with Kantrowitz. He extended his models of normal and diseased cardiac states to the cardiovascular system, testing their theories with experiments on animals at Rhode Island Hospital.

Jaron's success at building URI's program while continuing pathbreaking research in cardiovascular models and simulations resulted in Drexel University (Fig. 4) hiring him to direct its Biomedical Engineering and Science Institute. One of the oldest programs in the world, Drexel established its program in 1958 to retrain medical doctors as biomedical engineers. It had drifted as a program option in electrical engineering and then as an interdisciplinary institute "because it is very difficult to take somebody who was not brought up in the engineering culture and try to get the person to think in that way."

> When I came, I started recruiting more faculty members. We did not have our own tenure slots. I was the only person who was appointed full time, but my

[8]The National Library of Medicine has the Adrian Kantrowitz Papers, significant parts of which have put on line at http://profiles. nlm.nih.gov/ps/retrieve/Collection/CID/GN, visited 4 December 2014.

[9]Adrian Kantrowitz, Richard Cohen, Heinz Raillard, John Schmidt, and Daniel S. Feldman, "The Treatment of Complete Heart Block with an Implanted, Controllable Pacemaker," *Surgery, Gynecology and Obstetrics* 115 (October 1962), pp. 415–420; Adrian Kantrowitz, "Implantable Cardiac Pacemakers," *Annals of the New York Academy of Sciences* 111, no. 3 (June 1964), pp. 1049–1067.

[10]Quoted in Donald McRae, *Every Second Counts: The Race to Transplant the First Human Heart* (Berkley, 2007), p. 99.

[11]Adrian Kantrowitz, Steinar Tjonneland, Joseph S. Krakauer, Alfred N. Butner, Steven J. Phillips, W. Z. Yahr, M. Shapiro, Paul S. Freed, Dov Jaron, and Jacques L. Sherman Jr., "Clinical Experience with Cardiac Assistance by Means of Intraaortic Phase-Shift Balloon Pumping," *Transactions of the American Society for Artificial Internal Organs* 14 (February 1968), pp. 344–348.

Since the year of the interview, researchers have developed algorithms to automate the implementation of the pump, but they are not effcacious in all populations of cardiac patients; see Pena and Quall, pp. 324–332, especially p. 329.

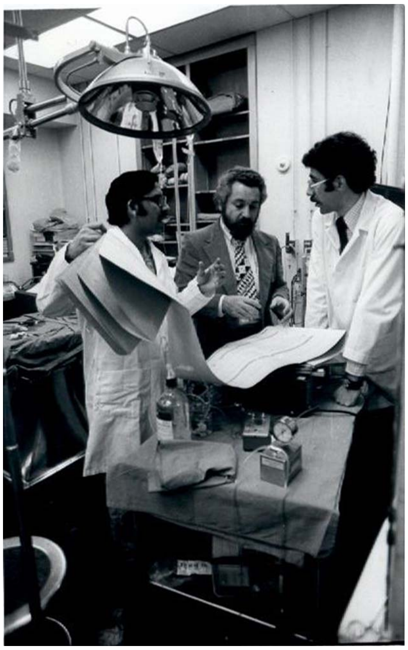

Fig. 3. *Dov Jaron, center, at the Rhode Island Hospital Research Lab, 1975. Image courtesy of University of Rhode Island Archives and Special Collections.*

tenure still resided in Electrical Engineering. We had a dozen or so faculty members who had either taught a little bit in the program or had some research interests in the program. I started building the graduate program. We did not have any undergraduate program. Within a fairly short time, maybe six or seven years, the number of our graduate students rose from the teens to about 120. The research funding that we were getting when I came was like \$200 000 or \$300 000 total for the institute, and we built it up to about two or three million dollars a year. It went very, very well.

IV. SABBATICALS AT THE NATIONAL SCIENCE FOUNDATION AND NATIONAL INSTITUTES OF HEALTH

In 1991, Jaron took a sabbatical to direct the National Science Foundation's Biological and Critical Systems division.

> I just wanted to have some reprieve from the Drexel environment for a while, and I found it very, very interesting. It was very rewarding and I learned a great deal. I did a lot of good, too, at NSF. I had a lot of accomplishments there, not the least of them was to change the division which became Bioengineering and Environmental Systems, elevating bioengineering, and making it much better known within the NSF.

Five years later, he took another two-year sabbatical to run the Biomedical Technology program at the National Institutes of Health's National Center for Research Resources, where he also served as associate director. Here the scale of biomedical engineering was significantly greater than that at NSF.

> It was similar in the terms of the responsibilities, but in terms of funding the program was five times as large as the NSF program. When I was division

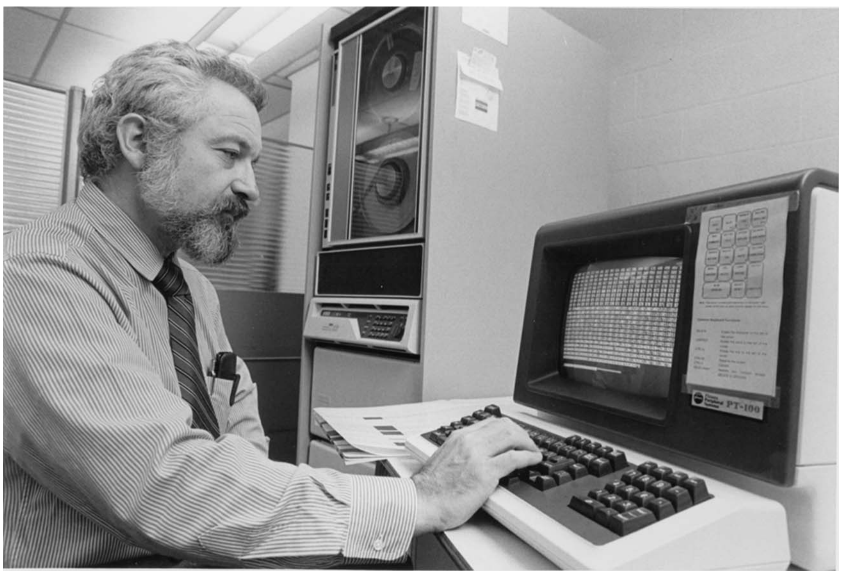

Fig. 4. *Dov Jaron working at a computer terminal at Drexel University, circa 1980. Image courtesy of the Drexel University Archives.*

director at NSF, my whole division had maybe $40 or $45 million, but the biomedical engineering part of it had only like $20 million. At NIH, I was in charge of over $100 million, which was a lot more.

Besides influencing the direction of funding, Jaron

put together a major conference in biomedical engineering that really, I think, changed NIH's view of biomedical engineering. Most of the people at NIH had never thought of biomedical engineering as a serious contributor to basic research in biology and medicine. They look at biomedical engineering sort of as a service profession—you tell biomedical engineering what you want to build and they build it for you. I think that having that major symposium in 1998 was really a major step for NIH.

In February 1998, over 750 people attended the first Bioengineering Consortium (BECON) conference in Bethesda, Maryland, USA, to show what NIH had underwritten and what it could do in the future through 110 posters and exhibits.[13]

As a result, NIH started looking at how applications are reviewed at NIH, and the fact that it is really difficult for biomedical engineering applications to get funded. They are changing that now, which is a very major change.

V. BIOENGINEERING AS A PROFESSION

After Jaron returned to Drexel, he resumed his own research on extending his cardiovascular model to include gas transport in the microcirculation and continued his efforts to broaden the professional field. This involved steering between the well-established and much larger groups of radiologists and medical imaging professionals, and the narrower perspective of IEEE's Engineering in Medicine and Biology Society (EMBS).

Ever since I was president of the EMBS [1986–1987] I have pointed out the very serious problem that the EMBS focuses only on those professionals whose roots are in electrical engineering. Biomedical engineering has become much more than electrical engineering oriented. As a matter of fact, the majority of biomedical engineers right now do not even know what an electrical engineering circuit is . . . . There are many more mechanical, chemical, information, computer, materials . . . . I think that you learn a great deal from what other people do and you come up with ideas you never thought could be applicable to your own specialty.

Jaron also looked forward to the creation of a new federal "Institute for Bioimaging and Bioengineering," whose name reflected the political compromise involved in gaining political and professional support.

The reason it was done that way is because imaging research has been advocated by the radiology community. The radiology community feels that they are not getting their fair share of grant support, and they are very, very strong and have a lot of money. Bioengineers are not very rich, so they do not have the same lobbying power that radiologists do. So the two committees agreed at least for a compromise, which generated much more support in Congress, but I still do not think it is going to fly because [Harold] Varmus [director of the NIH] is opposed to this. But of course, Varmus is leaving NIH at the end of the year, so that may change things all together—who knows.

The National Institute for Biomedical Imaging and Bioengineering was signed into law in December 2000 and funded with a budget of $US 278 million in 2002, a number that began increasing steadily from 2008 to $US 321 million in 2013.[14] Even before that, however, Jaron was aware that scientific and technological developments were redefining the place of biomedical engineers in society.

We are entering a new era. When we finish sequencing the genome, we will begin to understand how the genes relate to proteins and how they relate to cell function, how the cells behave, how tissues behave, and finally how whole organs and the organism behaves. I think the only people that will really be able to piece that picture together are biomedical engineers. The way scientists study something is by what is called the reductionist approach . . . . Engineers try to integrate. ■

[13]"Bioengineering: Building the Future of Biology and Medicine," Bioengineering Symposium report, June 4, 1998, https://web.archive. org/web/20041015093755/http://www.becon. nih.gov/report_19980228.pdf, accessed 8 December 2014. The acronym for the Bioengineering Consortium can be confused with BEACON, the Biomedical Engineering Alliance for Central Connecticut, which held its first symposium in October 1998, on biosensors, at Trinity College, Hartford, Connecticut, USA.

[14]See National Institutes of Health, "History of Congressional Appropriations, Fiscal Years 2000-2013," http://officeofbudget.od.nih.-gov/pdfs/FY15/Approp%20%20History%20by% 20IC%20through%20-FY%202013.pdf, visited 8 December 2014. Figures are not adjusted for inflation.