David Cardús (1922–2003), the physician of the space

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On June 1, 2003, David Cardús, a Catalan physician and scientist who had lived and worked in the United States for almost 50 years, died in Spring, Texas. Trained as a cardiologist, Cardús conducted research in a wide array of medical fields, including the effects of gravitation on human physiology, spinal cord injury rehabilitation, respiratory physiology, aging, and the use of computational and mathematical systems to analyze biological data. Throughout his life, he maintained close ties with Catalonia and Catalan language and culture, working actively to ensure an awareness of both in the United States. The tenth anniversary of his death is a good opportunity to remember him not only as an outstanding physician and scientist, but also as a passionate advocate of the interests of his country.

David Cardús was born in Barcelona on August 6, 1922. He studied at the Institut Escola, a public school whose core values were mass literacy and equal access to education. In 1939, following the Spanish Civil War, he moved to France with his father—his mother had died in 1933. In 1942, after his graduation in Arts and Science (Physics, Chemistry and Mathematics) from the University of Montpellier, France, he returned to Barcelona, and he was forced to serve in the army for four years. Afterwards he studied medicine at the University of Barcelona, earning his M.D. degree in 1949. He did his internship at the Clinic Hospital of the University of Barcelona and completed his residency, from 1950 to 1953, at the private Sanatorium of Puig de l’Olena, in Sant Quirze de Sanaüja, a small village in the mountains, north of Barcelona. During that time, despite the recent availability of antibiotics to treat tuberculosis, mountain air was still considered curative of the disease and was a therapeutic option adopted by those families who could afford it. During his time at the sanatorium, Cardús met Joan Colomines Puig (1922–2011), a laboratory physician who familiarized Cardús with the Dubos and Middlebrook hemagglutination test in the diagnosis of tuberculosis [1]. The Puig d’Olena sanatorium, which was in operation from 1933 to 1954, was more than a health center; it was a private hospital owned by Maria Plana, a woman who sympathized with Catalanists. Many of the people who had fled to France at the end of the Civil War but returned because the insecure conditions of German-occupied France, made a stop at Puig d’Olena before going to Barcelona. The sanatorium’s patient population included intellectuals and artists, such as the painter Antoni Tàpies (1923–2012), the poet Màrius Torres (1910–1942), who died in the sanatorium, and the writer, literary critic, publisher, and editor, both in Catalan and in Spanish, Josep Maria Castellet. The above-mentioned physician Joan Colomines went on to become the author of poetry, plays, and essays, as well as a political activist, first clandestinely, during Franco’s years, and later as a member of the Parliament of the Autonomous Government of Catalonia (Generalitat de Catalunya).

Political exiles tend to meet to maintain links to their countries and so did the Catalans in the countries that hosted them after the Spanish Civil War (1936–1939). In France, Cardús met Francesca Ribas, the woman he would marry. Her father, Francesc Ribas, had been a Conseller (Minister) in the Catalan Government during the Spanish Second Republic (1931–1939), and was the personal physician of the Catalan President, Lluís Companys, who was also an exile in France. (In 1940, Companys was arrested by the Nazi authorities and extradited to Spain, where he was accused by the dictatorship of militar rebelion; he was executed in Barcelona on October 15, 1940.) Once David Cardús and Francesca returned to Catalonia, she enrolled at the University of Barcelona, obtaining her M.S. in Pharmacy in 1956 and her Ph.D. in Pharmacy in 1960. That same year, the Cardús family moved to the United States. In Houston, she worked as a Research Associate at Baylor College of Medicine, a position she held from 1970 to 2000.
Between 1953 and 1954, Cardús was in Paris, on a scholarship awarded to him by the French Government that allowed him to specialize in cardiology at the Bucicot Hospital and La Pieté Hospital. There, he published his first scientific article (see Bibliography at the end). He then returned to Barcelona to become certified in cardiology, at the University of Barcelona. In 1957, with a scholarship from the British Council, he moved to Manchester, UK, where he worked at the Royal Infirmary of the University of Manchester. From 1957 to 1960 he was a Research Associate in the Department of Physiology of the Lovelace Foundation for Medical Education and Research (currently, the Lovelace Respiratory Research Institute) in Albuquerque, New Mexico, USA. During the 1950s, the Lovelace Foundation had expanded the scope of its research and was the USA’s premier center for research in aviation and space medicine, in the context of which its researchers had developed a protocol to test candidates for their fitness for space missions.

In 1960, Cardús settled in Houston, Texas, to work as a Research Associate at The Institute for Rehabilitation and Research (TIRR). He remained at the Institute until his retirement. During his tenure there he held various high-level positions, including Director of Research, Director of the Work Tolerance Laboratory, Director of the Cardiopulmonary and Vital Studies Laboratory, and Director of the Biomathematics Division. The TIRR is a teaching hospital of Baylor College of Medicine and the University of Texas Medical School at Houston, a leader in medical rehabilitation and research. Its roots go back to the Southwestern Poliomyelitis Respiratory Center, set up in the early 1950s, when poliomyelitis was a devastating disease in the United States. With the introduction of the polio vaccine, the incidence of the disease decreased dramatically and the expertise and know-how of the center were subsequently applied to the rehabilitation of handicapped patients suffering from other disabling diseases and injuries.

In 1966, Cardús obtained a Ph.D. in mathematics at the University of Michigan-Ann Arbor. He had a great interest in mathematics and sought to establish a connection between the life sciences and mathematics. He emphasized the importance of quantitative measures in medicine and biology and the need to apply mathematical models to the study of cardiac function. Later, he became interested in computer science and its application to the life sciences. Cardús realized that physiological data, such as temperature, pulse, and respiration rate, if expressed as discrete data points, could be processed in a computer almost instantaneously. If the data could be entered into a computer in real time, biological functions and any related changes could be studied as they were happening. Cardús even set up a system that, at his office in Houston, allowed him to record and analyze in real time data from a person performing exercises in Barcelona. The results could then be transmitted and visually displayed in Barcelona [4]. It is clear from his bibliography that his interest in these methods stems from as far back as the late 1960s. By 1970, he and his collaborator Lawrence Newton had published a paper describing the development of a computer technique that allowed the transmissions and long-dis-
In addition to his research and his clinical practice, Cardús pursued an academic career, not only at Baylor College of Medicine, where he had several appointments including Professor of Rehabilitation, of Physiology, and of Biostatistics, but also at Rice University, Houston, Texas, where he taught both mathematics and statistics. In 1970, he served as vice-chairman in the organization of a Gordon Conference on biostatistics. (The Gordon Research Conferences are prestigious scientific meetings with a long tradition; they were initiated in the 1920s to promote the exchange of ideas and knowledge at the research frontiers of the biological, chemical, and physical sciences.)

Both Cardús and Joan Oró—a Catalan biochemist who also settled in Houston [see Contrib Sci 2:579-594]—tend to be associated mainly with the work they did for the US National Aeronautics and Space Administration (NASA). However, the collaboration with NASA was only part of their research. Cardús studied the effects of weightlessness on the anatomy and physiology of astronauts. His early studies showed that a loss of gravity, such as experienced by astronauts in outer space, would compromise bone health, muscle tone, fluid distribution, cardiovascular function, and other biological factors. Cardús searched for a method to counteract these effects, by simulating gravity inside the space vehicles. He invented the artificial gravity simulator (AGS), which consists of a short-radius rotating platform capable of producing a centrifugal effect on astronauts’ bodies that replicates the gravitational effect humans experience on the Earth’s surface (Fig. 1). That rotating platform has been used both in spacecraft, to reproduce gravity, and on Earth, to study the effects of greater or lesser gravitational forces on human biological functions.

In addition, Cardús applied his research to health problems common in the normal population. He considered human physical activity at three scales: (i) the capability of performing certain functions, (ii) the optimization of these functions depending on the individual’s general health, and (iii) the adaptability of the individual to environmental changes. Based on these considerations, he used a short-radius centrifuge to study cardiovascular disorders in patients suffering from paralysis caused by spinal injury [3].

The scope of Cardús’ medical interests went beyond the strictly scientific to include social aspects, to which he devoted significant efforts. He believed in medical progress based on the prevention of a disease rather than on its eradication after it had become established in the body. He found a contradiction in references by health managers to a “health system” given that what actually interested them was disease, not health. Similarly, he found the term “Health Center” a misnomer, and “Medical Center” closer to the true aim of these institutions, since their focus was diagnosis and treatment rather than disease prevention [3].

The scientific output of David Cardús has been analyzed thoroughly by Jacint Corbella, in an article published in the journal of the Royal Academy of Medicine of Catalonia [2]. Corbella examined the production of Cardús, in terms of scientific articles indexed in Medline, regarding their distribution over time, the coauthors, and the topics of research. The 54 articles thus identified were published between 1965 and 1997, with the most productive year being 1967 (8 articles indexed). Wesley G. McTaggart and Carles Vallbona, Cardús’ colleagues at Baylor College, were his most frequent coauthors. Vallbona was also a Catalan physician and was already working at Baylor College when Cardús arrived [6]. The subjects of Cardús research, as reflected in his publications, can be summarized as follows: the physiopathology of the bladder, the adaptability of the individual to environmental changes. Based on these considerations, he used a short-radius rotating platform capable of producing a centrifugal effect on astronauts’ bodies that replicates the gravitational effect humans experience on the Earth’s surface (Fig. 1). That rotating platform has been used both in spacecraft, to reproduce gravity, and on Earth, to study the effects of greater or lesser gravitational forces on human biological functions.

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The achievements of great scientists are recorded in the articles and books they published throughout their careers. But this is not the case for many of their ideas and thoughts, unless they also published their memoirs or essays. Despite having spent more than half of his life abroad, David Cardús maintained his ties to his homeland, Catalonia, as well as his love of its language and culture. During one of his stays in Barcelona, in 1995, he talked about language during a radio interview. In that interview he mentioned that a friend of his has sent him the Dictionary of Catalan Language, which had just been published by the Institute for Catalan Studies, in Barcelona. Cardús said that he appreciated that gift very much and would make good use of it; besides, he added, he always thought of his friend Ricard each time he used the Dictionary. It is a shame that, today, with the publication of dictionaries on line, this kind of personal connection has been lost. R. Guerrero
Cardús belonged to a generation of Catalan scientists who emigrated to other countries to search for what they could not find in Spain, which was recovering from a civil war and was isolated internationally. Most of the country’s best researchers and those that might have been their mentors had either gone into exile or died during the war. In Houston, there were other Catalan researchers, not only physicians but also, for example, the aforementioned biochemist Joan Oró, who after teaching at Baylor College of Medicine became Full Professor of Biochemistry at Houston University; Carles Vallbona, Distinguished Service Professor of Community Medicine at Baylor College of Medicine; and Lluís Delclós, Margaret and Ben Love Professor in Clinical Cancer Care at M.D Anderson Cancer Center in Houston, Texas.

While all of these men were well integrated in their host country, they maintained their ties to Catalonia. because, as Pasteur said, even if science does not have homeland, scientist do. Cardús’ spirit still hovers over the AICS—currently presided by her daughter, Helena Cardús—which continues to promote Catalan culture in the United States.

References

David Cardús’ Curriculum Vitae and Bibliography

Note: This CV and list of publications is based on the list that one of us (R. Guerrero) received from Prof. David Cardús in 1997.

**Curriculum vitae**

Professor of Physical Medicine Rehabilitation, Baylor College of Medicine, Houston, TX
Adjunct Professor of Mathematical Sciences and Statistics, Rice University, Houston, TX

**Education**

1942: Bachelor of Arts and Sciences (Physics, Chemistry and Mathematics), University of Montpellier, France
1949: M.D. Degree Magna Cum Laude, University of Barcelona Medical School, Barcelona, Catalonia
1949-1950: (Internship) Clinic Hospital of the University of Barcelona
1950-1953: (Residency) Sanatori Puig d’Olona (Respiratory Diseases), Sant Quirze de Safaja, Barcelona
1956: (Certification) Postgraduate School of Cardiology, Diploma in Cardiology, University of Barcelona
1953-1954: Postgraduate Department of Cardiology of Hôpital Boucica and Hôpital de la Pitié, Paris, France
(Fellow, French Government)
1954-1956: Postgraduate School of Cardiology, University of Barcelona
1957: Department of Cardiology, Manchester Royal Infirmary, University of Manchester, England (Fellow, British Council)
1966: Summer Institute in Mathematics for Life Scientists, University of Michigan, Ann Arbor (National Institute of Health Trainee), Michigan, USA

**Major areas of interest**

Cardiology · gravitational physiology · preventive medicine · rehabilitation · aging

**Major research interests**

Exercise physiology (applications to space research, health and aging)
Rehabilitation medicine (applications to cardiac rehabilitation, bladder dynamics and body composition in extensive paralysis)
Application of computers and mathematical models to medicine
Application of benefit-cost theory to rehabilitation medicine

**Honors and awards**

University of Barcelona Medical School, M.D. Degree Magna Cum Laude, 1949
Fellowship of the French Government, 1953-1954
Fellowship of the British Council, 1957
Fellowship of the Institute of International Education, 1957-1960
Society Sigma Xi (Rice University Chapter), 1963
National Institutes of Health Trainee, 1966
American Urological Association 1st Prize for Exhibit on Clinical Research, 1967
American Congress of Rehabilitative Medicine, Gold Award for Scientific Exhibit, “Micturition Following Spinal Cord Injury”, 1967
Institut d’Estudis Catalans, August Pi-Sunyer Prize of Physiology for paper “A New Method for Respiratory Measurements in Man”, 1968
5th International Congress of Physical Medicine, 1st Prize for Scientific Exhibit, “Micturition Following Spinal Cord Injury”, 1968
Vice-Chairman, Gordon Conference on Biomathematics, 1970
Gold Medal for Demonstration on “Use of Computers and Telecommunications in Rehabilitation Medicine”, 6th International Congress of Physical Medicine, 1972
Member, Societat Catalana de Biologia, 1972
Charter Member, Society for Mathematical Biology
American Medical Association, Physician’s Recognition Award in Continuing Medical Education, 1974-1977
Member, Instituto de Cultura Hispánica de Madrid
Elisabeth and Sidney Licht Award for Excellence in Scientific Writing, The American Congress of Physical Medicine and Rehabilitation, 1980
Commendation of Isabel La Católica, awarded by H.M. King Juan Carlos de España, 1980
Medal Narcís Monturiol, awarded by the Generalitat de Catalunya (Autonomous Government of Catalonia) for his contributions in rehabilitation and space biomedical research, 1985
Catalunya Enfora Award, presented by the Institute of Iberoamerican Cooperation, 1987
Creu de Sant Jordi (St. George’s Cross), awarded by the Generalitat de Catalunya, 1992
Honorary Doctor’s Degree (Doctor Honoris Causa), Autonomous University of Barcelona, Spain, 1993
Joan d’Alòs Award. Centre Cardiovascular Sant Jordi, Barcelona, Spain, 1996

Professional experience and background
Research Associate, Department of Physiology, University of Barcelona, 1954-1955
Research Associate, Department of Physiology, The Lovelace Foundation, Albuquerque, New Mexico, 1957-1960
Research Associate in Physiological Studies, Texas Institute for Rehabilitation and Research (TIRR), 1960–
Director, Work Tolerance Laboratory, TIRR, 1960–
Active Medical Staff, TIRR, 1960–
Director of Research, TIRR, 1962-1966
President Active Medical Staff, TIRR, 1967-1968
Chairman, Information Sciences Committee, TIRR, 1968-1978
Director, Cardiopulmonary and Vital Studies Laboratory, TIRR, 1969-1978
Director, Biomathematics Division, TIRR, 1970–

Academic appointments
Professor, Department of Rehabilitation, Baylor College of Medicine, 1969–
Professor, Department of Physiology, Baylor College of Medicine, 1973–
Adjunct Professor of Mathematical Sciences, Rice University, 1970-1988
Adjunct Professor of Statistics, Rice University, 1989–
Director, Biomathematics Program, Baylor College of Medicine, 1966-1968
Graduate Executive Committee, Baylor College of Medicine, 1968-1969
Chairman, Biomathematics Committee, School of Graduate Studies, Baylor College of Medicine, 1968-1969
Visiting Professor of Physiology, Fac. of Medicine, Universidad Autónoma de Barcelona, 1970

Consultant positions
Scientific Advisory Council, Common Research Computer Facility, Texas Medical Center, Houston, 1965-1966
Rehabilitation Subcommittee, Texas Heart Association, 1967-1969
U.S. Public Health Service, Division of Health Facilities, Planning and Construction Service, 1967
Mathematical Association of America, 1968
Veterans Administration Hospital, Houston, Texas, 1969–
Community Medicine, Harris County Hospital District, 1974–
Pan American Health Organization, 1977–

Professional organizations and positions held
American College of Chest Physicians, 1960–
New York Academy of Sciences, 1962–
Harris County Medical Society, 9th District Medical Society, 1963–
Texas Medical Association, 1963–
American Congress of Physical Medicine and Rehabilitation, 1964–
American Physiological Society, 1964–
Federation of American Societies for Experimental Biology, 1964–
Houston Academy of Medicine, Texas Medical Center Library, Scientific Advisory Committee, 1964–
American Association for the Advancement of Science, 1965–
American College of Cardiology, 1965–
American Heart Association, Texas, Affiliate, 1967–
Biomedical Engineering Society, 1970–
Automedica Advisory Editorial Committee, 1970–
American Association of University Professors, 1971–
American College of Sports Medicine, 1971–
Society for Mathematical Biology, 1972– (Board of Directors, 1982)
Methods of Information in Medicine, Editorial Board, 1977–

Grants awarded for the following research projects

- The Effects of Bedrest on Various Parameters of Physiological Function. Co-Principal Investigator. NAS-9 1461 (1963-1965)
- General Clinical Research Center for Chronic Illness. Chairman of the Clinical Research Center Advisory Committee. DHEW FR-00219 (1963-1970)
- BUCM Computational Research Center Program. Director of Mathematics and Statistics Program. FR-00259 (1965-1968)
- A Work Tolerance Evaluation Research and Training Unit for a Cardiac Rehabilitation Program. Principal Investigator. DHEW 13-P-55235/6 (1969-1974)
- National Research and Demonstration Center for Heart and Vessel Disease Demonstration Project. Establishing an Outpost in the Community for Screening and Rehabilitation in Ischemic Heart Disease. Principal Investigator. DHEW HL-17269 (1974-1975)
- Rehabilitation Research and Training Center no. 4. Principal Investigator in the following projects. DHEW 16-D-5681/6 (1969-1980)
- Total Creatinine in Patients with Extensive Muscular Paralysis Estimated by Radioisotopic Tracer Methods (R-22 1969-1973)
- Exercise and Lipids Profile in Ischemic Heart Disease (R-139.1972-77) Quantitation of ST-segment Changes in Exercise ECG Using Computer Techniques (R-159.1974-75)
- Quantitation of ST-segment Changes in Exercise ECG Using Computer Techniques (R-159.1974-75) Cardiac Rehabilitation Program for Patients with Myocardial Ischemia and Arterial Hypertension [R-179 (PR-7) 1977-1980]
- Evaluation of Physiological Responses and Diagnostic Criteria for the Application of Exercise Stress Testing within the Biomedical Space Program. Principal Investigator. NAS 9-14661 (1975-1977)
–Gz and +Gz experimentation with the AGS. Principal Investigator. NASA (Subcontract USRA 9910-29-103 ) (1992-1994)
Nutritional Status of Persons with Spinal Cord Injury: Relationship to Community Integration. Co-Principal Investigator. NIDRR (Grant No. H133B40011-95 (1993-1999)

**Student doctoral theses**

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Smith, Laura K. “Passive motion as a stimulus to ventilation in man.” Baylor College of Medicine

Lehman, Jim R. “Quantitative aspects of the inter-conversion of androgens in rat testis and ovary.” Baylor College of Medicine

Batiz-Solorzano, Sergio (1979) “On decisions with multiple objectives: Review and classification of prescriptive methodologies, a group value function problem, and applications of a measure of information to a class of multi-attribute.” Rice University


Chan, Shou Chao (1979) “Benefit-cost analysis in rehabilitation programs.” Rice University

Littell, Elizabeth H (1980) “Neural regulation of blood flow in on-working muscles.” Baylor College of Medicine


**Post-doctorate fellows in Dr. Cardús’ programs**

Ernest Pevney. Medical School of Komenius, University of Bratislava, Czechoslovakia

Luis I. Vera. School of Medicine, University of Zaragoza, Spain

Ramón Segura. School of Medicine, University of Sevilla, Spain

Eduardo Larrousse. School of Medicine, University of Zaragoza, Spain

Francisco Fuentes. School of Medicine, University of Valencia, Spain

Alfred Johnston. Department of Electronics, Rice University, Houston, Texas

Joe Murdock. Mathematical Sciences, Rice University, Houston, Texas

Jacobo Rosenthal. School of Medicine, Universidad Central de Venezuela, Venezuela

Domingo Hernández. Departamento de Rehabilitación, Ministerio de Sanidad y Asistencia Social, Caracas, Venezuela

Ramachandra Srinivasan. Electrical Sciences Department, California Institute of Technology, California

Andrés Pie. Department of Physiology, University of Zaragoza, Spain

Enric Domingo. School of Medicine, Universitat Autònoma de Barcelona, Spain

Norman Fuentes. Departamento de Rehabilitación, Caja Costarricense del Seguro Social, Costa Rica.

Branco Lovic. Institute Niska Banja, University of Nis, Yugoslavia

Philippe Vidal. École Nationale Supérieure d’Ingénieurs de Constructions Aéronautiques (ENSICA), Toulouse, France

Laurent Bonsergeant. École Nationale Supérieure d’Ingénieurs de Constructions Aéronautiques (ENSICA), Toulouse, France
Publications

1954–1964
Cardús D (1960) Estudios sobre la capacidad humana para el esfuerzo mecanico (Studies on the human capacity to perform mechanical work). University of Barcelona-Fontiss, Barcelona, Spain
Cardús D, Hoff HE (1963) Pulmonary ventilation response to the metabolic action of 2,4-dinitrophenol. Arch Int Pharmacodyn 144:563-570

1965–1974
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1985-1995


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