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Article *in* The International journal of developmental biology · August 2020

DOI: 10.1387/ijdb.200050ma

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Int. J. Dev. Biol. 65: 93-101 (2021)
https://doi.org/10.1387/ijdb.200050ma

THE INTERNATIONAL JOURNAL OF DEVELOPMENTAL BIOLOGY
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Six decades of scientific pan-Americanism - an interview with Jorge E. Allende

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ABSTRACT Jorge E. Allende is a biochemist trained in the United States of America who has been a professor at the University of Chile since 1961. He has served in many leadership positions in both Chilean and international scientific organizations and academic institutions. He led the International Cell Research Organization, the Latin American Network of Biological Sciences and obtained the Chilean National Science Prize. He belongs to the Chilean Academy of Sciences and is a foreign member of the National Academy of Sciences (USA) and also of the National Academy of Medicine (USA). During his career, besides leading a highly successful research group, he was instrumental in generating an *esprit de corps* among Latin American scientists of all fields in biology starting in the late 1960's. He began a longstanding tradition by organizing advanced training courses for young scientists from the region who would not have otherwise had the opportunity to experience the latest methods and concepts in biological research, courses that had world leading researchers as instructors. A constant focus of his efforts consisted in promoting the establishment of postgraduate programs in biology throughout the continent, coordinating international funding programs aimed at scientific development in the third world and, more recently, advocating for science education among children and school teachers as the only way to achieve scientific literacy in our societies. In this interview, we explore how these issues were addressed by him and his counterparts in other Latin American countries, at a time when they had to start, essentially, from scratch.

KEY WORDS: *Chile, science education, Latin America, biochemistry*

Un ser sin estudios, es un ser incompleto
(An uneducated being, is an incomplete being)
Simón Bolívar

Background

Jorge Eduardo Allende Rivera (Fig. 1A), was born to a Costa Rican mother and Chilean father in the city of Cartago, Costa Rica, in 1934. He lived in Costa Rica until age 12, where he was able to grow up surrounded by the exuberant fauna and flora of the tropics. His family then moved to Santiago, Chile, where he attended junior high school in a Catholic school run by German priests. Here, he continued to be exposed to nature further cementing his interest in science. His father's work in Chile's diplomatic corps took them to New Orleans, in the U.S.A. in 1949, where he attended Jesuit High School and excelled in the humanities, Greek and Latin. He later entered Louisiana State University in 1953 where he majored in Chemistry with a minor in History. There, Jorge lived at the Pan American House, where Latin American expatriates could find a home away from home (Fig. 1B). With a clear desire to continue his career by obtaining a PhD in biochemistry, in 1957 he entered the doctoral program at Yale University led by Dr. Joseph Fruton. Among his classmates was Catherine Connelly, whom he later married and with whom he started a lifelong scientific partnership. During his doctoral studies, which he carried out with Dr. Fred Richards, he met some of the most important figures in the ongoing molecular biology revolution: Frederick Sanger, Severo Ochoa, Max Perutz, James Watson and Arthur Kornberg, among others. He became interested in the mechanism of protein synthesis so, nearing the end of his PhD, he applied to the lab of Nobel Laureate Fritz Lipmann at Rockefeller University (Fig. 1 C,D). Before moving to New York, he was visited by the then Rector of the University of Chile, Juan

Abbreviations used in this paper: ICRO, International Cell Research Organization; NIH, National Institutes of Health; OAS, Organization of American States; RELAB, Red Latino Americana de Biología (Latin American Network of Biological Sciences); UNDP, United Nations Development Program; UNESCO, United Nations Educational, Scientific and Cultural Organization.

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Submitted: 29 January, 2020; *Accepted:* 2 March, 2020; *Published online:* 20 August, 2020.

ISSN: Online 1696-3547, Print 0214-6282

Gómez Millas, who offered him a job in Santiago if he wished to return to the country. He accepted but clarified that he would do so after his postdoc. He did spend six months at the University of Chile in 1961 where he met the small but vibrant group of biochemists at the Medical School: Julio Cabello, José Calvo and Hermann Niemeyer, who occupied an old dilapidated building that housed the Institute of Physiological Chemistry and Pathology. Although the scientists there lacked equipment and resources, their spirit was contagious and it convinced him that he would be able to continue his research there if he returned to Chile. Back with Lipmann, where he spent a little over a year, he witnessed the race to solve the genetic code between the groups of Marshall Nirenberg and Severo Ochoa. While Lipmann did not enter this competition, they decided to approach other aspects of protein synthesis and Jorge worked on the isolation and characterization of the translation elongation factors. He was able to get to know and befriend the main characters involved in the discoveries of the time such as Francis Crick, Marshall Nirenberg and Walter Gilbert. In order to avoid competing in the hottest field in science upon moving to their new jobs in Chile in late 1962, Jorge and Catherine, now working together, decided to focus on aminoacyl-tRNA synthetases, work that was supported by a grant from the Jane Coffin Childs Memorial Fund. Taking with them all the reagents they could carry (and a newborn son, yours truly), they managed to do the right experiments in a few months and publish their first paper in the *Journal of Biological Chemistry* six months after arriving in Santiago. Another four papers in that journal would follow between 1965 and 1970, mostly concentrating on the enzymology of the synthesis of peptidyl-tRNAs. During a visit to the U.S. and a short stay in Jim Watson's lab, they agreed to spend a sabbatical year in Marshall Nirenberg's lab at the NIH, which took place in 1966-67 with the support of a Guggenheim Fellowship, just as the genetic code was finally being resolved.

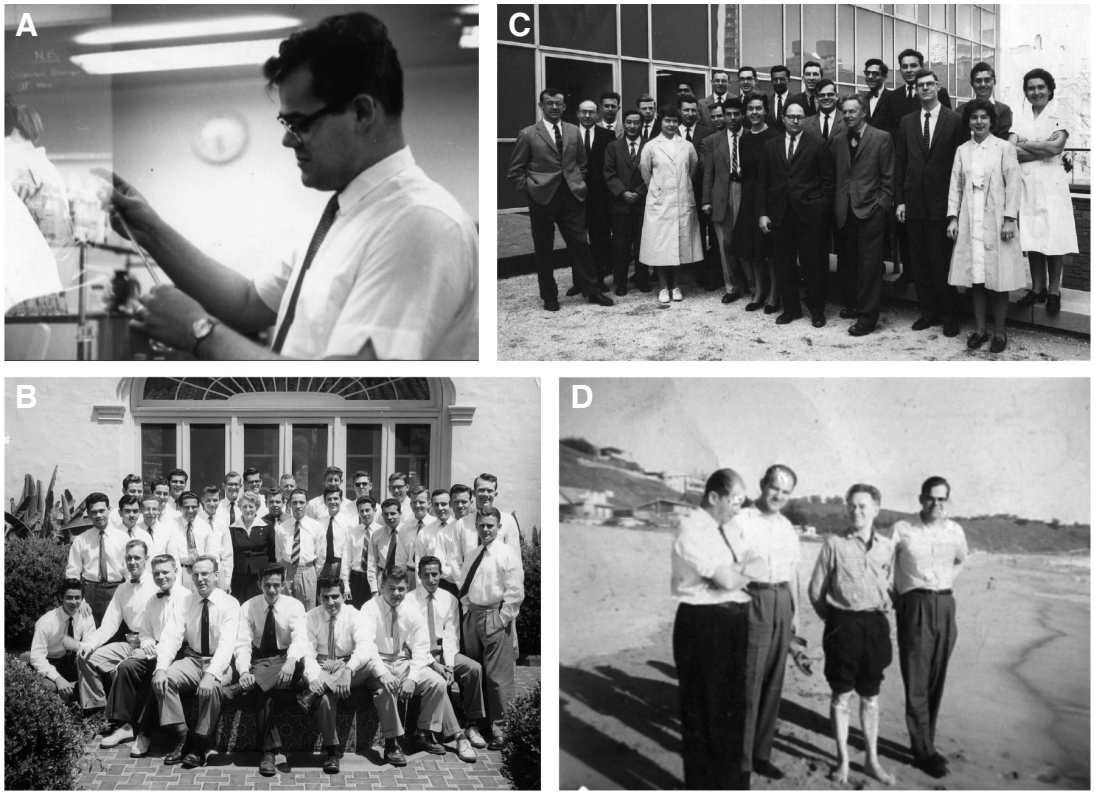

Fig. 1. Education and early career of Jorge E. Allende. (A) *Jorge E. Allende as a PhD student at Yale University, 1958.* **(B)** *Students at the Pan American House, Louisiana State University, Baton Rouge, in 1953. Jorge is at the far back, center.* **(C)** *The laboratory of Dr. Fritz Lipmann in 1962 at The Rockefeller University. Jorge is at the center, standing behind Nobel Prize winners Lipmann and Daniel Nathans.* **(D)** *Jorge (far right) and Fritz Lipmann beside him, during a visit he made to Chile in 1963.*

During the late 60's, Jorge had the opportunity to travel to conferences in Argentina, Brazil and Mexico, where the biological sciences were undergoing a renaissance with the arrival of the new biochemistry brought back by Latin American colleagues trained in the U.S. and Europe. He conceived of an idea to seek support for developing graduate programs in Latin America, a desire shared by his peers in the region including Luis F. Leloir of Argentina. Thus, Jorge embarked in an effort to find international funding that would stimulate regional science with an independent character, in which PhDs could be trained locally. It was the only way to conceive of the birth of a community that could reach the critical mass needed for scientific development in the continent. As a first step, Jorge proposed to organize bi-yearly international training courses in molecular biology aimed specifically at Latin American students. This idea was stimulated by his own experience as a participant in a Cold Spring Harbor course on cell culture, led by Dr. Gordon Sato. In 1968, with funds from the International Cell Research Organization (ICRO), the first of these courses was held in Santiago (Fig. 2A). Many young Latin American's had their first exposure to modern molecular biology techniques in these courses and they helped to establish a network of these scientists that lasted decades, with impacts felt to this day. Among future developmental biologists involved in these courses were Eddy de Robertis (course of 1970; Fig. 2B) and Alain Ghysen (1972) who was a postdoc in the Allende-Connelly lab (Fig. 2C). After an interruption due to the sabbatical period Jorge and Catherine spent in the Sato lab at UCSD (1972-74), the courses continued from 1975 to 1988. These were difficult years in Chile, as well as in most of Latin America, as there was a cruel military dictatorship that had little interest in the development of science or the universities. Nonetheless, many prominent scientists came to Chile, including Severo Ochoa (Fig. 2D) and Eddy de Robertis (now as a professor), to participate in the teaching of the emerging techniques in

molecular biology. After the return of democracy to the country, more courses and symposia were organized by Jorge from 1990 to 2005, and they increasingly turned to more specific topics such as recombinant DNA techniques, PCR, the human genome and developmental biology (Fig. 3).

Jorge Allende served many roles in the promotion of science in Latin America but perhaps the most important one was his push to get international organizations to fund research grants and training opportunities for scientists in the region. The support of ICRO, UNESCO/UNDP and OAS, together with the tireless work of a small group of committed scientists in most of the countries involved, were key. Eventually, the Latin American Network of Biological Sciences (RELAB) took on this role though it has struggled to sustain governmental support in recent years.

A more recent motivation for Jorge has been the promotion of a new paradigm for scientific education in schools. He launched a program led by the University of Chile and modeled on initiatives in the US and Europe where science is taught to children through curiosity building and experimentation, rather than formal lectures or rote learning. The program has evolved into further initiatives such as a portable labs program and research projects by high school students, with emphasis on training of the teachers. All of these endeavours have been specifically directed at underprivileged public schools. The projects have taken on a life of their own after Jorge retired from active science in 2009 though he still leads the effort to extend the idea across the country and abroad. At this writing, the portable lab initiative is supported locally by a modest and intermittent contribution of the Chilean Ministry of Education and has relied mostly on international funds (the Wellcome Trust being the most noteworthy). The RELAB council has supported the extension of the portable labs idea to other countries and it has taken hold in Costa Rica, Mexico, Argentina and Brazil. The efforts of Jorge Allende to promote science education led him to be awarded the puRkwa Prize in 2007. This is an "international prize for the scientific literacy of the children of the planet" awarded annually by the école nationale supérieure des mines of Saint Etienne and the French Academy of Sciences. With the prize money, he and his wife Catherine Connelly created a foundation (the *Allende Connelly Foundation*) that promotes the portable lab initiative, teacher training and excellence in graduate studies in biology at the University of Chile.

Questions and answers

Career and choices

When you were growing up and once you decided to initiate a scientific career, which Latin American scientists (if any) did you consider role models or were known to you?

For a child, it is really impressive to grow up in a place like Costa Rica where nature's exuberance is just impossible to miss and it attracted me greatly. However, I was there only for primary school, so I wasn't exposed to formal science at that time. When my family and I moved to Chile, I attended junior high school at the *Liceo Alemán*, run by German priests who had emigrated after the First World War. One of the priests, Father Teodoro, took us frequently to the hills on the outskirts of Santiago to collect plants, insects and small animals. He was the biology teacher and I believe I impressed him very much when I presented to the class my research on the human circulatory system; my mother, who was an artist, had made drawings of the blood vessels and heart for me. I lived very close to the public library and, in my free time, I walked over and read all I could get my hands on, especially adventure tales. But I also came to read Paul de Kruif's book *Microbe Hunters*, which I found so inspiring that I believe that it was one of the main factors in making me become a scientist. After only two years in Chile, my family moved again, to the United States. We settled in New Orleans and I attended Jesuit High School, where, for four years I essentially had no science classes except for math. The emphasis was on the humanities so I learned Latin, Greek, History and Literature, though I did win a state gold medal in algebra.

As I graduated from high school, my family decided to return to Chile. However, my intention was to stay in the U.S. and go to the university there. I was able to get a fellowship covering both tuition and living expenses because of my good grades so I entered Louisiana State University (LSU). At that point I knew I wanted to become a scientist. Reaffirming this decision was in part due to my professor of microbiology, Dr. Stravinsky, who had us carry out small research projects with bacteria. Antibiotics had been discovered a few years ago and I was very impressed by experiments in which I had to look at bacteria incubated in penicillin derivatives that grew without dividing, forming long tubes because of the absence of a cell wall. I can say that from then on, I was hooked on science and never looked back.

So, to answer the question, I did not know any Latin American scientists at all when I started my career, so I can't say that I was inspired by a specific role model. I recall though, that news from Chile brought the name of Dr. Eduardo Cruz-Coke, a renowned medical doctor who was active in politics and had been Minister of Public Health. He founded the Chilean Biological Society and was instrumental in promoting the establishment of the first research labs in biology at the medical school at the University of Chile. When I had started my PhD in Biochemistry at Yale, by coincidence, the Director of the program, Dr. Fruton, received two thesis works written by two Chilean biochemists, in Spanish. Since he didn't understand the language, he passed them on to me and they turned out to be by two of Cruz-Coke's disciples: Dr. Hermann Niemeyer and Dr. Julio Cabello. These works made me aware that in Chile there was an active scientific community. Towards the end of my PhD, another crucial event happened: the Rector of the University of Chile at the time, Juan Gómez Millas, toured the United States and interviewed with many Chilean expatriates. I had the fortune of meeting him in New Haven and he asked what I was doing there. When I told him I was about to obtain my PhD in biochemistry, he said the University was looking for scientists and that he would hire me as soon as I became available. I accepted the offer and later on, after a short postdoc with Fritz Lipmann, I took a position at the University of Chile where I have been ever since.

You were trained in the USA. Why did you return to Latin America after your training, considering you could have stayed and made a successful career there?

I would say that my settlement in Latin America was a mixture of feeling more at home here and having the right opportunities at the right time. During my time at LSU, my circle of friends was mostly made up of Latin Americans, of many nationalities. I lived at the Pan American House, a place that housed students from

all over Central and South America (Fig. 1B); I later became President of the House's Student Association and even ran for President of LSU's Student Union. Comparing the culture of my Latin American peers and that of the North Americans made me realize that Latins, while diverse, share many idiosyncrasies and values that were more in line with my own. I became a believer in the Bolivarian ideal of a single, United States of Latin America as possibly the only way out from underdevelopment.

I also became politically involved and, during a three month trip to Chile in 1958, I participated in the presidential campaign that was mobilizing the new generation intensely. At this time, I felt that my place was to develop my career in Chile, where important things were happening, and I wanted to be a part of it. My wife Catherine, a native of Massachusetts, also obtained an academic position at the University of Chile, and she generously accepted to move to Chile and to join me in this adventure on the far side of the world.

Latin American integration

In the 1960's and 70's, biological science in Latin America was in its infancy and, in Chile, the community was minuscule. How did you come to know your colleagues in other countries and begin to form a network?

It all started after a course I took at Cold Spring Harbor Laboratories in 1967. It made me realize that intensive theoretical and practical short courses allowed one to learn a whole new area of biology and to start new research projects by investing only a few weeks of time. That course in particular (Animal Cell Culture, led by Dr. Gordon Sato) was very illuminating for me; I attended because I wanted to move my research towards *in vivo* biology which was a trend that many scientists were following. Few people in Latin America were doing this at the time so I thought I could break some ground by bringing it to Chile. It turned out that cell culture required substantial resources which I did not have so I didn't actually set up such a lab then (soon after, I found that an excellent -and cheaper- alternative to cultured cells for *in vivo* studies was to use *Xenopus laevis* oocytes). However, and more importantly, I decided to replicate the idea and format of the course on a topic that I was more familiar with and I began planning to have a Molecular Biology Course. It was to take place in Santiago in 1968. As I said before, Latin American integration was always on my mind and I started to look for funding to carry out the course with international speakers, on the one hand, but also having Latin American students, who I knew, did not have access to this type of training locally. A remarkable coincidence then happened. I was contacted by a professor, Henrique Tono, of the Universidad del Valle in Colombia. He told me that he had received funding from the International Cell Research Organization (ICRO, a subsidiary of UNESCO), to organize a Molecular Biology course in Cali, 1968, and that he was inviting me to take part in it as an instruc-

Fig. 2. International courses at the Allende Lab. (A) *Participants in the First International Molecular Biology course held in Santiago, 1968. Jorge is at the back, far right.* **(B)** *Second International Course in Molecular Biology, Santiago, 1970. Among instructors were Gordon Sato (second from left, front row) and Alexander Spirin (seventh from left, front row). Eddy de Robertis was a student in the course (third from the left, third row).* **(C)** *The Allende lab in 1972. Seen are Jorge (at center), Catherine Connelly (2nd row, right) and Alain Ghysen (far left).* **(D)** *Jorge with Dr. Severo Ochoa in 1982, when he came to participate in one of the International Molecular Biology courses.*

tor. I congratulated him on the initiative but I mentioned that I was organizing a similar event to take place in Chile. In a very generous gesture on his behalf, he said that we shouldn't compete and that he would like to offer to transfer the ICRO funding to the course I was organizing. This action was hugely impactful in my career and set me on a path that would drastically change the nature of my role in science.

I contacted many of my friends from my time at Rockefeller and asked them to be instructors in the course, which they all happily agreed to. They were Thomas Conway, François Chapeville and James Ofengand, all of which had recently started their positions in the U.S. or Europe and they, nonetheless, agreed to spend a month in Chile teaching (Fig. 2A). The whole endeavour wasn't easy. In addition to the logistical complexities involved, 1968 was a year of worldwide student protests. In Chile, we had to ask permission from the students, who had occupied the medical school campus, to allow us to go on with the course; they graciously agreed. I recall another remarkable story from that course. There was a general strike right before the course which involved the postal service. As we were expecting all of the international applications to arrive by mail, we had no way of receiving them in time. I spoke to the postmaster to see what we could do and he said "I can't help you. All of the arriving mail is left in sacks in our storage room." And then, sarcastically, he added "Perhaps you would like to look through them?" To his surprise, I accepted his challenge and brought all of my students and assistants to the main post office and we went through a huge number of bags of mail. To our credit, not a single application went unfound.

Despite all of the stress and inconveniences, the course was a huge success: the students went home having received advanced training and we were able to incorporate many of the techniques brought by our colleagues into the lab. Most importantly though, I was more convinced than ever that this was a straightforward way to create networks among Latin Americans, to bring the younger generation of scientists of the region into the mainstream of modern biology and to stimulate regional cooperation and pooling of our limited resources.

After the 1968 course I was able to secure continued funding by ICRO for the following courses, that took place between 1970 and 1988. Each one had its own challenges. In 1970, it took place in the final days before the Chilean presidential elections and, in 1972, Chile was under the presidency of Salvador Allende. We were able to invite Dr. Alexander Spirin from the Soviet Union in 1970 (Fig. 2B) and we had a Cuban student attending. Later on, starting in 1975, our courses were held under the Pinochet dictatorship and participation became more restricted. In addition, many colleagues from abroad expressed concern that ICRO/UNESCO funds were being used to support activities in a country where human rights were not respected. Two of the instructors we had invited, Gordon Sato and John Gurdon received letters asking them to boycott the 1975 course, in a way similar to the boycott imposed on South Africa because of apartheid. Both Sato and Gurdon replied that they intended to participate regardless, because their aim was to support their colleagues in Chile and the rest of Latin America who were enduring such highly adverse conditions. ICRO agreed with them and maintained its support. (In the end, Dr. Gurdon was not able to attend, though he visited our lab many times after that). The courses continued to evolve, following the advances in the field of the late 70's and early 80's. We introduced the first experiments in genetic engineering to our students and, later, we had Heiner Westphal of NIH carry out a demonstration on transgenic mouse technology together with Chilean developmental biologist, Luis Izquierdo. For one of the courses, we managed to invite Dr. Severo Ochoa, who was at that time back in Spain leading the Instituto de Biología Molecular at Madrid. It was a great honor to have him come and visit us and contribute to our course (Fig. 2D).

The courses helped to strengthen our PhD programs. Together with Niemeyer and the rest of our community, we started the first formal PhD program in Chile in 1971, a doctorate in Biochemistry, with participation of professors from the major Chilean universities. The courses also helped the students who attended to find postdoctoral positions with the invited lecturers and instructors.

After the successful international courses of the late 1960's and early 70's, what motivated you to create a network of biological scientists in the region?

In 1973, when I was on sabbatical at UCSD, I learned that the UNDP was starting a large research center in Hungary. At the time, the head of the regional development programs at UNDP was Gabriel Valdés, who had been the Chilean Foreign Relations Minister under President Frei in the late 60's. I happened to travel to Atlantic City for the FASEB conference where I met with many Chilean expatriates training or working in the United States, and learned from them that most had no intention to return to Chile. Since I was nearby, I went to see Mr. Valdés in his New York office, right across from the UN headquarters, and told him about the catastrophic "brain drain" that was ongoing in Chilean science. He agreed with me that it was critical to start a program to support Chilean science but, at the time, the funds allocated to our country had all been used. However, he said, there were "regional" funds available, which required the commitment of a minimum of three countries to establish an international development program. He asked me what kind of program I would propose under that framework and I told him that I thought that the best investment would be towards graduate programs in Latin America. At the time, we had our very young program in biochemistry, while Argentina, Mexico and Brazil had decades of history in training PhDs. But in the rest of the continent, doctoral programs were practically nonexistent. We agreed with Valdés that we should favor the less developed nations of the Andean region and he suggested that I travel to the candidate countries to explore their interest in such a program. He offered me a consultant role for this task but I declined, indicating that I would rather continue being a scientist, but I did agree to make the trip and to coordinate the project. I used all of the contacts I had made during the international courses I had run and also asked my Chilean colleagues to provide names of scientists in the countries I would visit. As Chile would be the lead country within the initiative, I told my friends about my conversation with Valdés and they enthusiastically contacted our government to get the approval for entering the project. These were the latter days of Salvador Allende's presidency and, as we were waiting for their reply, the military coup took place and the universities suffered the strong repression that came with the change of regime. After about six months, the new authorities expressed that they agreed to be part of the project (after all, it was free money) and I called Valdés again to let him know we were set to go. The selected nations were Colombia, Ecuador, Perú, Bolivia and Chile. I made the tour in April of 1974 and went from north to south as I was travel-

Fig. 3. The Fourth Santiago Southern Summer Symposium on "Genes and Genomes" was held in 1996. *Among the speakers was James Watson (sitting in front, near the center). Jorge is at the extreme left of the photograph (standing, near pillar) as is the author (sitting, second from left).*

ing from California. In Colombia, I met with Dr. Alvaro Alegría at the Universidad del Valle who introduced me to the authorities at COLCIENCIAS and university leaders. In Ecuador, I didn't know anyone but I came upon Dr. Claudio Cañizares at the Universidad Central in Quito; he was instrumental in contacting me with the government officials at the national planning office. I also visited the Pontificia Universidad Católica del Ecuador where I was surprised to find two excellent young women biologists with vibrant research projects. Dr. Laura Arcos-Terán, trained in Germany in *Drosophila* polytene chromosomes, and Dr. Eugenia Del Pino, a developmental biologist who had started work on the fascinating amphibian *Gastrotheca riobambae*. Eugenia and I have been good friends since that moment. I was very impressed when I visited her lab many years later, in 2003, and saw the growth in infrastructure and the large research group she had built. As I continued south, I came to learn that each country had its own idiosyncrasies and political peculiarities. For instance, Perú was under a left-wing military dictatorship led by General Velasco Alvarado and it was frightening to see soldiers in the streets (I hadn't been back in Chile since the coup). There was particular animosity towards Chile (Pinochet was a right wing dictator) so it was hard to convince my colleagues and authorities that the project was a good faith effort to help with their scientific development. I met with Dr. Marino Villavicencio of the Universidad de San Marcos and Dr. Alberto Cazorla of the Universidad Peruana Cayetano Heredia. I also befriended a young biologist, José Alvarez. In the end, both the scientists and government agencies expressed they intended to be part of the project and I continued on to Bolivia. I had learned that the President of the Bolivian Academy of Sciences was a geneticist, Dr. Luis Felipe Hartmann, who had also been Rector of the Universidad San Andrés. He contacted me with the Ministry of Education where I presented the idea and they were very adamant about demanding that Chile would have to give them access to the Pacific Ocean before arrangements of any kind were to be made with that country[1]. I expressed that I was not there representing the Chilean government but an international organization and that I thought that the best way to integrate our countries was through these types of initiatives. My next and last stop was Chile, my first time back under Pinochet's rule. It was shocking to witness the fear and despair of the people and the disarray of the scientific establishment; many colleagues had been detained or exiled and the universities were being rid of their capacity to be critical and politically relevant. Nonetheless, the army general in charge of CONICYT, the Chilean scientific development agency, was very happy to be able to seem useful and he agreed to incorporate Chile into the network.

I returned to the U.S. after my five country tour and started the official negotiations to apply for the funds. Of the five nations, only Perú declined to participate. I traveled with Valdés and his staff to Paris to negotiate the funding process which had to go through one of the international agencies; it was decided it should be UNESCO. The directorate of UNDP approved funds in 1975 (US$300,000 for the first year) and asked me to lead the initiative; I stated I would not leave my university position nor my research and that I could do it part time, to which they agreed. My official position was that of Technical Coordinator. One of my first missions was to incorporate Perú, which fortunately happened almost immediately.

[1] Chile and the Bolivia-Perú Confederation were engaged in a war over territory in the nineteenth century, after which Bolivia lost its access to the Pacific. In 1975, Pinochet and Bolivian dictator Banzer signed an agreement to end Bolivia's maritime isolation but it was never realized.

I also began work to try and integrate Venezuela into the network, another country that was at a similar stage of scientific development, despite its much more prosperous economy due to its oil industry. They entered in 1976. That was followed by the incorporation of Argentina (1977) and Brazil (1978). The national committee in Argentina was led by Dr. Leloir and in Brazil by Dr. Francisco Lara and some of his young collaborators including Hugo Armelin, Mari Cleide Sogayar, Rogerio Meneghini and Hernán Chaimovich.

The network functioned well for a variety of reasons. First, we decided against privileging a single country with large infrastructure or to act as headquarters. Second, we favored fellowships for young trainees, especially from the less developed countries to those that had a longer tradition. Thirdly, we insisted that the committee in charge of the project would be made up of equal numbers of members from each country and that there would be government representatives as well as scientists from each nation. Finally, in addition to mobility funds, short and long term fellowships, and courses, we allocated resources to support small research grants. For the latter case, we decided to require that these projects be bi-national in nature, with a less developed country pairing with a more developed one to try and decrease the degree of inequality among participating nations. The project was renewed successively and lasted a total of 10 years, much longer than the typical length of international cooperation projects, with a total budget of about 3 million dollars. The end of the UNESCO project was followed by a proposal to sustain the basic idea of the network through an initiative supported by the interested countries themselves. UNESCO provided some seed money for the initiative which we called RELAB, for Red Latinoamericana de Ciencias Biológicas (Latin American Network of Biological Sciences). Key to its support was the Director General of UNESCO, Federico Mayor, as it has been difficult for many of the countries to pay their dues. Nonetheless, RELAB is still functioning and we have a meeting planned for this year in Buenos Aires where we will celebrate 45 years of the network's existence.

Many fundamental discoveries in biology were made during the course of your career. What approach did you take to try to educate the public about these advances in an underdeveloped country with a small scientific community?

I have always felt a need to communicate and educate people about what science is about and to share the excitement of new discoveries. Recently, I have put all of my energy behind my educational projects but, early in my career, there weren't as many options for disseminating knowledge as there are now. At one point, I convinced the editor of one of the most important newspapers in Chile, *El Mercurio*, to publish articles about science. I was inspired by the news that an international team was going to begin to sequence the human genome, and I thought the public should know about it and what it meant. I was given space for a recurrent series of articles that lasted for about six years. They were published every two months or so in the Sunday supplement on arts and culture, with a very large readership. I wrote articles on everything from the genetics of behavior, to AIDS, to the genome of *Saccharomyces* and evolution. At one point I thought of compiling this collection into a publication of some sort as it followed an important period in the history of modern science, told in real time. While I never got around to it, it was still a wonderful opportunity to explain all of the concepts and facts behind the molecular biology and genomic revolution of that period.

Another effort I made much earlier, in 1970, was to write a short monograph on protein synthesis. This was part of a collection of monographs written in Spanish and funded by the OAS that were distributed all across Latin American schools and universities at very low cost. I have been amazed at how many people seem to have read my monograph as, to this day, people will come up to me and mention that they read it back in the 70's when they were studying. It goes to show how a small investment in educational materials can have a long lasting impact on society.

On Science

What scientific contribution from your lab are you most proud of?

That's a tough question. When I was incorporated into the National Academy of Sciences of the United States, one of the contributions that was highlighted was our work on aminoacyl tRNA synthetases and the formation of the translation complexes. That work took place immediately after Catherine and I set up our lab in Chile, where we had little resources and we were just starting out. I also think that our pioneering work with *Xenopus* oocytes in which we used them to study mRNA stability and translation *in vivo* was very significant. As an idea put forth, I would say that my 1988 review in *FASEB J.* had an impact. There, I describe several contexts in which GTP binding proteins (G proteins) change their affinities for other macromolecules depending on GTP binding and also that GTPases can modulate these affinities. In other words, I postulated that GTPases are critical regulators of many, very different, biological processes. I got this general idea from a meeting that I organized when I was on sabbatical at the NIH in 1985, where I invited colleagues working on signal transduction, protein synthesis, cytoskeletal dynamics and other fields that usually did not intersect, but that had this mechanism in common.

Although you were trained as a biochemist, your research spanned diverse aspects of molecular and cellular biology. Did you ever consider questions relating to the field of developmental biology?

In 1967, when I was with Nirenberg for my first sabbatical, I heard a talk that John Gurdon gave at Columbia University. There he described the injection of DNA into *Xenopus* oocytes and I was very impressed by the opportunities that this system offered for further analyzing the behavior of nucleic acids in an *in vivo* system. I went to visit John Gurdon in 1971, who was precisely at that time moving his lab from Oxford to Cambridge University. In fact, I arrived on his very first day at Cambridge and found him already injecting *Xenopus* eggs and ready to teach me. He showed me all of his tricks including how you could pull microinjection needles by hanging, I think, a one shilling coin from one end while the filament heats the glass; the precise weight of that coin generated a tip of the right size for *Xenopus* egg injections.

Later on, in Gordon Sato's lab, I tested out the system for the first time and decided that *Xenopus* was an ideal animal model for these kinds of experiments in a place like Chile, where it was still out of our reach to have cell culture facilities. I remember the title of my first talk when we returned to Chile in 1974: "Crossing the *in vitro* - *in vivo* barrier". We started importing frogs from South

Africa, their native habitat, and this led to an inadvertent ecological disaster for Chile. During one of the times we purchased frogs and had them shipped to us, the animals were held up at the Santiago airport customs office because of a lack of paperwork. An unsolvable bureaucratic issue prevented the frogs from entering the country and the agriculture official in charge of disposing of the detained biologicals was tasked with incinerating everything. He took pity on the smiling frogs and simply let them go in a pond near the airport. It turns out that the Chilean climate and geography are similar to South Africa's and the frogs felt quite at home here. Today, *Xenopus laevis* can be found happily inhabiting a large extension of the Center-South region of Chile and, sadly, they have displaced some of the native species of amphibians. As the only silver lining I can think of that came out of this disaster is the fact that ourselves and other scientists could, from then on, easily acquire frogs from local sources. Our colleagues Roberto Mayor and Juan Larraín, who both have used *Xenopus* embryos for a number of years in their research, obviously benefitted from this calamity.

John Gurdon came to visit us several times here in Chile and Catherine and I visited him as well in Cambridge on a couple of occasions. However, we never really got into developmental biology. With the frog oocytes, we eventually began studying the phosphodiesterase that hydrolyzes cyclic AMP. We could inject cAMP into the oocytes and measure the enzymatic activity *in vivo*. Later, we looked at how adenylate cyclase was related to oocyte maturation. In our work with casein kinase, we did examine its expression and role in several developing organisms, including *Xenopus*, *Drosophila* and zebrafish embryos.

On Science education

Lately, you have been an advocate for scientific education across all Latin America. Can you tell us about that experience and the reception this effort has had in Chile and in other countries?

I came to realize that, at the end of the Twentieth Century, the great advances in molecular biology, genomics and biotechnology required that secondary school students should start to learn of these concepts in their schools. Unfortunately, in most countries in Latin America, the institutions responsible for training secondary school teachers did not have an academic staff that was trained in these advances. In 1998, together with my colleagues at the Faculty of Medicine at the University of Chile, we organized a theoretical and practical course in molecular biology and genomics aimed specifically at secondary school teachers. The response of the teachers, most of them from one of the large public schools in Santiago, the *Instituto Nacional*, was very enthusiastic and encouraged us to continue offering this opportunity in subsequent years.

But my passion for education in science really took hold in 2000 when I went to a meeting in Tokyo, in which all of the world's academies of science gathered. (That meeting was the launch of the Inter Academies Panel, IAP). I had been advocating for science education in the Chilean Academy for some time so I was invited to speak about this at the Tokyo meeting together with Pierre Léna, the famous astrophysicist and member of the French Academy, and Bruce Alberts, President of the U.S. National Academy of Science (NAS). In my presentation, I showed drawings made by children that depicted scientists as grumpy old men with white robes who were either torturing animals or making bombs. I asked the audience "How do we expect children to want to become scientists if they think of us in this way?" A few months later, I visited Bruce in Washington DC and he showed me the work the NAS together with the Smithsonian Institution were doing. The National Science Resource Center had established a program of eighteen modules that involved mobile labs that visited elementary schools and taught science based on inquiry. I immediately thought that this wonderful idea had to be replicated all over the world, especially in Latin America, so our teacher training courses began to incorporate participation of both teachers and instructors from other countries. These participants, in turn, began to think of replicating the idea in their own countries. In 2005, courses for teachers were held in Argentina, organized by Alberto Kornblihtt at the University of Buenos Aires, and Costa Rica, led by Ana Victoria Lizano at the University of Costa Rica.

Fig. 4. Interacting with the scientists of the future. (A) *At the El Salitre elementary school (Pudahuel, Chile) that was part of the ECBI program, in 2006 (Credit: Dirección de Comunicaciones, Universidad de Chile).* **(B)** *With high school students participating in one of the portable labs in the town of Linares, Chile, in 2017 (credit: Radio VLN, Linares).*

While the teachers thought the courses were very useful, they also confessed that they were very frustrated by not being able to share with their students that which they considered the most didactic and exciting component of the course which was the experimental part. Obviously, this could not be implemented by them on their own since, in general, secondary schools in our countries lack the modern scientific equipment needed to carry out such experiments. I proposed in 2001, in a chapter I wrote in

a book published by the Pontifical Academy of Sciences, that this feedback from the teachers strongly advocated for the introduction of a versatile, cheap and mobile system of laboratories that could be brought to the schools, in order that the students could then carry out the experiments that the teachers experienced in the universities. We can get an idea of how slowly things advance in education as it took us 10 years to find an institution willing to finance this initiative. In 2011, the Wellcome Trust opened a worldwide call for proposals that would contribute to inform societies about the great advances of the life sciences in the last decades. That same year, the Regional Executive Council of RELAB met and we decided that three member countries, supported by their national universities would apply. These were the University of Chile, the UNAM of Mexico and the University of Costa Rica. We obtained the funding, implemented portable labs and organized theoretical and practical courses in all three countries. Importantly, our funds allowed us to provide fellowships to biology teachers from neighboring countries as well.

Today, in Chile, we have labs in molecular biology and genetics, enzymology, developmental biology and two that we are implementing in microbiology and immunology. This turned out to be an effective way to engage young minds and introduce them to the world of science and we now challenge them to come up with research projects of their own, after they have done the experiments that are included in the portable lab experience. In our database, we have thousands of surveys which reflect the joy that the young people have felt as they participated in the portable labs program[2]. The contrast they make between the "before" and "after" this experience is remarkable. We have had international panels of education experts come and evaluate the program and they are truly impressed by its achievements[3].

In 2008, I was invited by Bruce Alberts to write an editorial in Science about these ideas and I think it has had an impact on many people and institutions. For instance, in Chile, we were involved in the beginning of the ECBI program, for *Educación en Ciencias Basado en la Indagación* (Science Education Based on Inquiry). It has been immensely successful, having been implemented across the country, mainly in public elementary schools, and it has been supported by the Chilean Ministry of Education for many years (Fig. 4). About 2,500 children have been impacted by this program to date. And I must say, when we asked the children that had been through ECBI to draw what they thought a scientist looked like, we found they depicted groups of them, not solitary men, lots of women and work that looked constructive and peaceful.

I still feel that we have not won the battle to convince the funders and governments, especially in Latin America, about the importance of promoting the value of science in society. But we have the evidence to show that it does, in fact, make a difference.

[2] Visit: www.laboratoriosportatiles.cl (in Spanish). The section "Opiniones" has the testimony of students who have participated.

[3] The international evaluation report by a panel of experts can be found in the following page (English version available): https://laboratoriosportatiles.cl/informe-de-expertas-internacionales-sobre-la-implementacion-de-laboratorios-portatiles

Acknowledgements

The author wishes to thank Dr. Eugenia del Pino for the opportunity to interview Jorge Allende despite the self-evident conflict of interest of the author. The interview took place on January 11th, 2020 in Santiago, Chile. M.A. is funded by ANID/FONDAP/15090007 of the Agencia Nacional de Investigación y Desarrollo (ANID), Chile. All of the photographs are the property of Jorge Allende except for those shown in Figure 4, where the credits are indicated in the captions.

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