Int. J. Dev. Biol. 65: 29-47 (2021)
https://doi.org/10.1387/ijdb.200181mc

THE INTERNATIONAL JOURNAL OF DEVELOPMENTAL BIOLOGY
www.intjdevbiol.com

Developmental Biology in Chile: historical perspectives and future challenges

MIGUEL L. CONCHA*[,1,2,3] and ISKRA A. SIGNORE[1,2,3]

[1] Institute of Biomedical Sciences, Faculty of Medicine, Universidad de Chile, [2] Biomedical Neuroscience Institute and [3]Center for Geroscience, Brain Health and Metabolism, Santiago, Chile

ABSTRACT Developmental Biology is a growing discipline in Chile. It started in the 1950s when Luis Izquierdo challenged the traditional descriptive perspective of embryology and comparative anatomy to explore the mechanisms underlying the origin of form. After this initial drive, Claudio Barros, beginning in the late 1960s and Juan Fernández, in the late 1970s, contributed with unique and complementary facets to the early growth of the discipline. In the 1980s, the community of developmental biologists created its first forms of association together with the reproduction biology community, and in 1993 the first international course of developmental biology was organised. During the 1990s and 2000s, a group of young investigators arrived in Chile after postdocs in Europe and the US to build the first research centres of developmental biology, fostering the discipline to an unprecedented level. In the 2010s, as these centres consolidated, a stream of young developmental biologists established new labs at several institutions, expanding the community size and broadening its scope. The recent organisation of developmental biology meetings fostered the sense of community and nurtured the need of formal organisation, setting the bases for the foundation of the Chilean Society for Developmental Biology. Today, the community of developmental biologists is a mix of young and experienced investigators working in a variety of geographical locations, institutions, topics and model organisms. These characteristics are a strength of an active community that is pushing the discipline to the next level, aiming to make it a relevant actor in national and international settings.

KEY WORDS: *Developmental Biology, Chile, history, challenge*

Introduction

Developmental biology is a growing discipline in Chile. Its origin can be traced back to the 1950s when Luis Izquierdo, an intellectual humanist and pioneer scientist, challenged the traditional descriptive perspective of embryology and comparative anatomy that dominated teaching and research at Chilean universities to explore the mechanisms underlying the origin of form. The community of Chilean developmental biologists was small at the outset and remained as such for many years. However, in the last three decades, a growing number of young developmental biologists expanded the scope of the discipline, covering a broader spectrum of topics and model organisms. This article aims to both provide a first historical perspective on the rise of developmental biology in Chile and discuss the current state of this discipline in the country, recognising its strengths and challenges towards the future.

Elucidating the circumstances that established developmental biology as a discipline in Chile has been a challenge as all leading founders passed away. Thus, we had to investigate science repositories, articles, books and historical documents from universities and scientific societies, and combine this information with personal perspectives obtained from interviews of scientists that witnessed

Abbreviations used in this paper: AUCAB, Asociación Universitaria y Cultural Andrés Bello; LAZEN, Latin American Zebrafish Network; PUC, Pontificia Universidad Católica de Chile; PUCV, Pontificia Universidad Católica de Valparaiso; RiBiD, Red de Investigadores en Biología del Desarrollo; UA, Universidad Autónoma de Chile; UACH, Universidad Austral de Chile; UBO, Universidad Bernardo O'Higgins; UCH, Universidad de Chile; UDD, Universidad del Desarrollo; UDEC, Universidad de Concepción; UM, Universidad Mayor; UNAB, Universidad Andrés Bello; UNESCO, United Nations Educational, Scientific and Cultural Organization; UOH, Universidad de O'Higgins; USS, Universidad San Sebastián; UV, Universidad de Valparaiso.

***Address correspondence to:** Miguel L. Concha. Laboratory of Experimental Ontogeny, Institute of Biomedical Sciences, Faculty of Medicine, University of Chile, PO Box 70031, Santiago, Chile. Tel: +56 229786875. E-mail: mconcha@uchile.cl - https://orcid.org/0000-0003-3353-9398

Supplementary Material (3 figures and 3 tables) for this paper is available at: https://doi.org/10.1387/ijdb.200181mc

Submitted: 22 June, 2020; *Accepted:* 14 July, 2020; *Published online:* 27 August, 2020.

ISSN: Online 1696-3547, Print 0214-6282

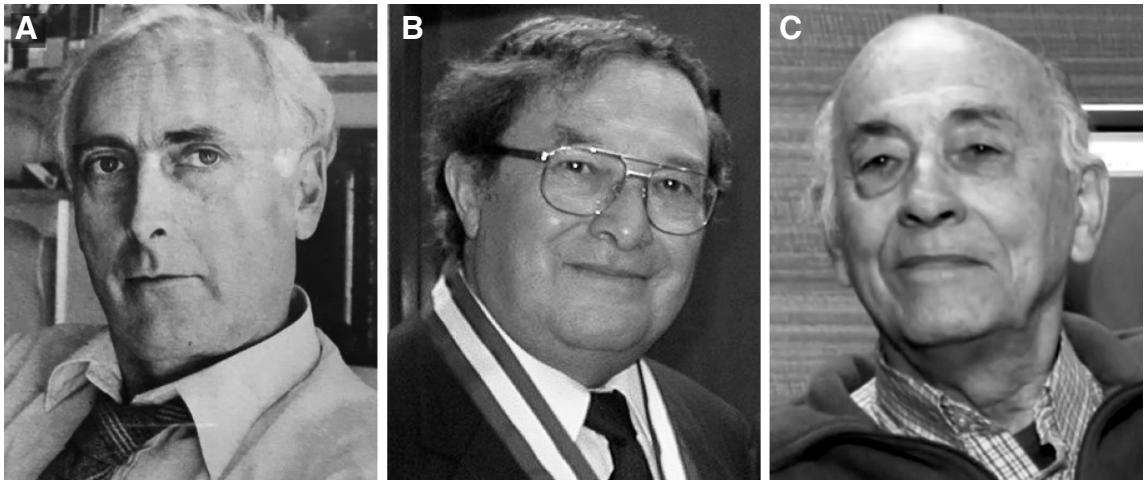

Fig. 1. Leading founders of development biology in Chile. (A) *Luis Izquierdo, circa 1990.* **(B)** *Claudio Barros, circa 2002.* **(C)** *Juan Fernández, circa 2010.*

the rise of the discipline mostly as students or collaborators of the leading founders. We had digital access to most relevant information. However, some old documents were only present as physical copies (e.g. some proceedings of scientific society meeting), and we could not access them as libraries shut down in the context of SARS-CoV-2 pandemic. Despite these constraints we succeeded in identifying the key players and milestones that guided the rise of developmental biology in Chile. Nevertheless, all historical research is potentially incomplete and subject to personal interpretation, especially when the information is limited. Therefore, we consider this manuscript not as the ultimate source but rather as the first documented historical approach to the subject.

The start of developmental biology in Chile (1950s - 1960s)

The reasons that explain the emergence of a new scientific discipline in a country are often multidimensional. Science ecological aspects such as the size, complexity and level of organisation of the scientific community, the political context that guides science and university activities, and the extent of integration and exchange of the local scientific community with the world, are all relevant factors to be considered. However, they are often insufficient. The vision of a scientist, or a group of them, that excel among their peers is fundamental to generate a collective need of transformation that breaks paradigms within the scientific community. This is what happened in Chile from the 1950s and had Luis Izquierdo as its main protagonist (Fig. 1A).

Luis Izquierdo: an intellectual humanist with a modern view of science and university life

Luis Izquierdo was a fascinating character. He was born in a large family with preeminent celebrities along his maternal branch including Vicente Huidobro (one of the most outstanding Chilean poets), Juanita Fernández Solar (a Chilean catholic nun venerated by the Catholic Church as Santa Teresa de los Andes) and Miguel Serrano (a diplomat, philosopher, occultist, novelist and white supremacist) (Lennon Zaninovic, 2012). In this peculiar family atmosphere, Luis Izquierdo became interested in philosophy. He also had the opportunity to travel to Europe, acquiring a vast cultural background and the humanistic aura that was so characteristic of him. He studied Medicine, but never practised the clinic. Instead, he turned his interest into science and university life, becoming a leading researcher in the field of developmental biology and a prominent educator and defender of university causes (Barros and Schatten, 1993). According to his peers, he was a bearer of a dazzling intelligence, critical spirit, creativity, fineness, and characteristic bravery in the public life. For him, "ideas were always the important thing, and then the courage to defend them" (Devés, 1993; SBCH, 2019)[1]. He led several causes related to science and education at universities and their role in society, and his ideas were always ahead of his time. For instance, he proposed radical concepts about the mission of the university, the power of interdisciplinarity and how university government should be parliamentary to express the irreducible complexity of its community better (Izquierdo, 1987). He also advocated for developmental biology to be a principal articulator for the teaching of basic biological concepts in Medicine, providing a natural link between the knowledge of the cell, the process of cell differentiation and tissue/organ formation, and the structural properties of the organism (Izquierdo, 1983).

Luis Izquierdo played directive roles in different institutions of Chile[2]. He was also a co-founder of the Faculty of Sciences of the *Universidad de Chile* (UCH) (1965) (Muñoz Galvez, 2015) and of

[1]The following example illustrates the courage of Luis Izquierdo to defend essential ideas and his international stature. In 1981, Luis Izquierdo was dismissed from Universidad de Chile (UCH) after defending its autonomy during the Pinochet dictatorship. He received immediate national and international support (one of the first letters of support was from Anne McLaren, a pioneer British developmental biologist). The government had to rectify its decision, and the rector of the UCH, who at that time was assigned by the military government, reached an agreement to reinstate Luis Izquierdo at the Faculty of Sciences through a deal with the Chilean Biology Society (SBCH, 2019).

[2]Luis Izquierdo was president of the Chilean Society for Cell Biology and AUCAB, Director of the Biology Department of the Faculty of Sciences in two periods, President of the Postgraduate Committee, member of the Presidential Commission of Superior Education, President of the FONDECYT Council of Sciences and promoter of the new high school baccalaureate project.

the *Asociación Universitaria y Cultural Andrés Bello* (AUCAB; 1981), an association that gathered academics from different disciplines to generate a free space for discussion and reflection about the values, problems and organisation of the university system, during the military intervention of universities after the Pinochet coup of 1973 (Errázuriz, 2018). In summary, he was an intellectual and a respected political figure within the academic and scientific institutions of Chile, and according to some of his colleagues "was even more than the causes he led" (Devés, 1993). For this, it is surprising that Luis Izquierdo and his contribution to Chilean science and education have not yet received the acknowledgements they deserve. Perhaps this omission is the reflection of his tragic death at a relatively early age as a consequence of Creutzfeldt–Jakob disease, which interrupted a brilliant career that was taking him to the top of Chilean science.

Luis Izquierdo and the first days of developmental biology in Chile

Luis Izquierdo graduated from Medicine at the UCH in 1953 (Fig. 2A). At that time, he already was interested in developmental biology. He also had academic connections with the *Pontificia Universidad Católica de Chile* (PUC) and obtained a Rockefeller Foundation fellowship[3] to visit Albert Dalcq and Jean Brachet, two distinguished scientists from the Brussels School of Embryology working at the *Université libre de Bruxelles* in Belgium (Fig. 2B) (Barros, 1980; The Rockefeller Foundation, 1954; Vargas *et al*., 2005). Albert Dalcq was famous for his contribution to the concept of *morphogenetic potential* and the role of interacting gradients and fields during early amphibian development while Jean Brachet contributed to understanding the role of RNA (Mulnard, 1992; Thieffry, 2001). When Luis Izquierdo visited Brussels, Albert Dalcq had already reoriented his research from amphibian to mammalian embryology using cytological and cytochemical methods, focusing primarily on cytoplasmic RNA, the development of which had been surmised by Jean Brachet. Luis Izquierdo used rat embryos and methylene blue as a vital stain to reveal the presence of metachromatic cytoplasmic grains that predicted the fate of the early blastomeres. This work resulted in his first two papers developmental biology papers (Izquierdo, 1954, 1955) in a topic that he would continue investigating for the rest of his life.

After his return to Chile in 1955, Luis Izquierdo was appointed as Professor of General Biology at the PUC Medical School to organise teaching in biology and research in developmental biology (Fig. 2C). He created a biology course that went beyond the mere description to discuss the central problems of biology combining evolution, genetics, cell biology and embryogenesis. This course, which had exceptional value for its depth and solidity, supported for many years the training of basic biology not only for students but also for the academic staff (Barros, 1980). Luis Izquierdo also launched developmental biology research in Chile (Fig. 3). At the PUC, he interacted with a group of pioneer scientists of the emerging school of experimental biologists, which inspired and promoted research and the training of scientific thinking in students. Among them, Juan de Dios Vial Correa was passionate about microscopy and played a crucial role

Fig. 2. Luis Izquierdo. (A) *Just Graduated from Medicine at the UCH, 1953.* **(B)** *A daily lunch with the group of Jean Brachet in Brussels, circa 1954.* **(C)** *The lab of Luis Izquierdo at the PUC, circa late 1950s. Luis Izquierdo is first on the left.* **(D)** *With his lab and colleagues from the developmental biology community at the Faculty of Sciences of the UCH, 1982. From left to right: Lilio Yáñez (photographer of the Biology Department), Alfredo De Ioannes (visiting professor, PUC), Manolo Echeverría (student from the Izquierdo lab), Juan Silva (animal nursery keeper), Margarita (laboratory assistant), Pablo Lois (Master student from the Izquierdo lab), Nancy Olea (Medical Technologist from the Fernández lab), Juan Fernández, Soledad Sepúlveda (PhD student from the Izquierdo lab), secretary, cartoonist, Verónica Téllez (Master student from the Izquierdo lab), María Inés Becker (professor from the Izquierdo lab), Luis Izquierdo, Carlos Doggenweiler (professor from the Izquierdo lab). Other lab members missing from the picture are Soledad Fernández and Teresa López, both medical technologists working with Luis Izquierdo.*

[3]The Rockefeller Foundation had a post-war international program that promoted the well-being of humanity throughout the world, supporting science in various fields and countries. In Chile, it funded fellowships for research visits abroad and grants to conduct research locally. Fellowships were pivotal in the scientific training of Luis Izquierdo, Claudio Barros and Juan Fernández, the three Chilean scientists that contributed most to the early rise of developmental biology in Chile. Claudio Barros also received a grant to initiate his developmental biology lab at the PUC after returning from his PhD in the USA.

in the acquisition and knowledgeable application of the "first electron microscope to be used in Chile" (Torrealba Ruiz-Tagle, 2013). In collaboration with him, Luis Izquierdo extended the research performed in Brussels to describe the ultrastructure of the early preimplantation rat embryo. This work resulted in the publication of the first developmental biology paper (to our knowledge) in the history of the country (Fig. 3) (Izquierdo and Vial, 1962).

Luis Izquierdo was convinced about the importance of centralising the teaching and research in non-applied biological sciences at universities and, in 1961, elaborated a program for the creation of a Biological Science Institute at the PUC. Most colleagues shared the relevance of this idea, however, the project failed to obtain institutional support and rested for almost ten years until it materialised only in 1970 (Vargas *et al.*, 2005; Vargas, 1980). Luis Izquierdo started looking outside the PUC and found a niche at the UCH. The idea of organising a scientific pole at the university to provide scientific training in any field of thinking was already under discussion and led to the creation of the Institute of Sciences in 1962. Two years later, a group of visionary scientists including Luis Izquierdo, extended this idea to found the Faculty of Sciences of the UCH (see a historical revision in (Muñoz Galvez, 2015)). In this new faculty, Luis Izquierdo became Professor of the Biology Department and continued his research of mammalian preimplantation development (Fig. 2D; Fig. 3). Among the sci-

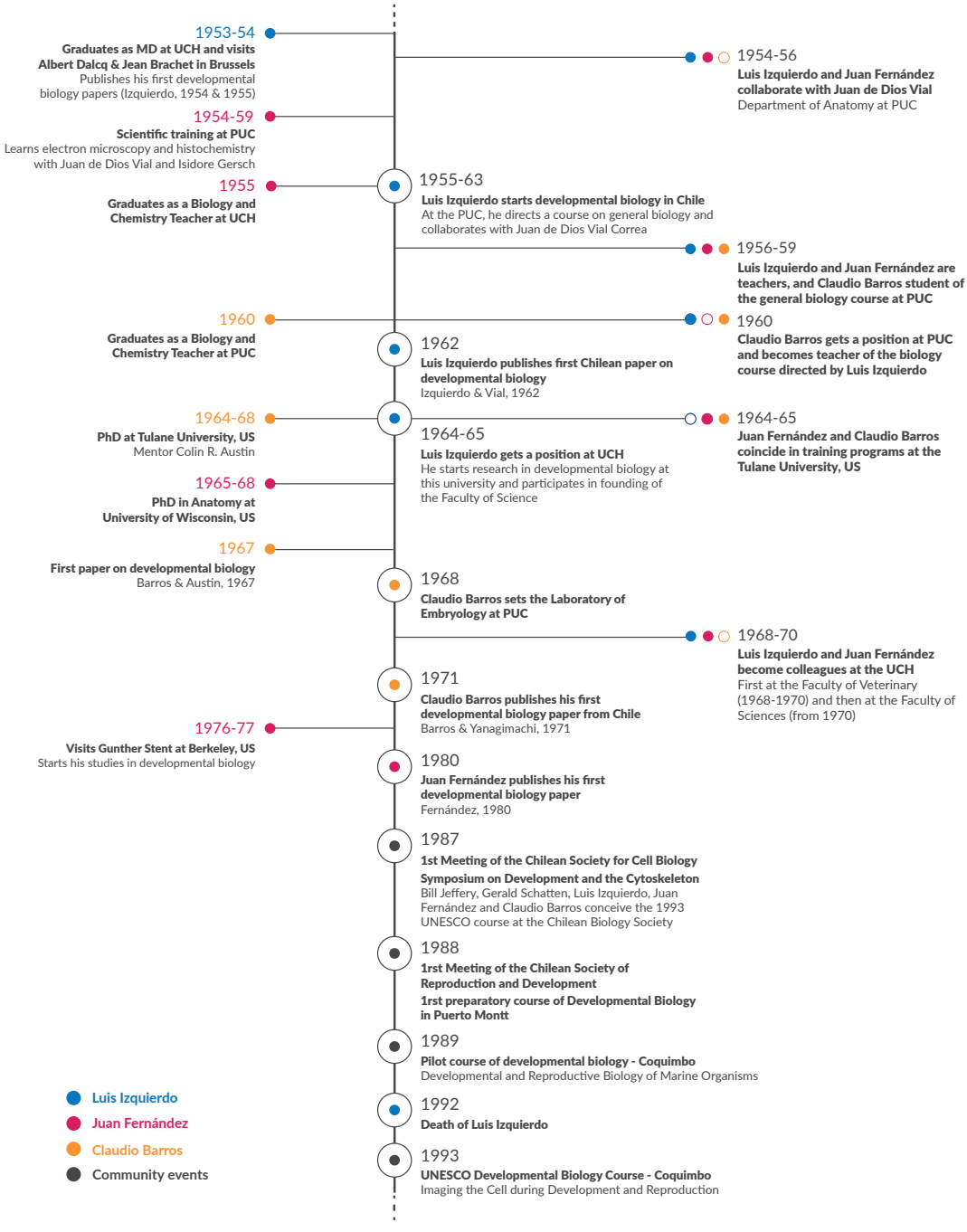

Fig. 3. Chronology of events leading to the early rise of developmental biology in Chile (1953 to 1993). *The milestones that marked the rise of developmental biology in Chile are indicated with large circles along a vertical temporal line that progresses from top to bottom. Small coloured circles indicate the specific contribution of Luis Izquierdo (blue), Juan Fernandez (red) and Claudio Barros (orange) to some of these events. Using the same colours, the column on the left indicates events in the individual scientific careers of Luis Izquierdo, Claudio Barros and Juan Fernández, while the column on the right highlights places and circumstances in which they coincided while establishing their scientific careers. Details are given in the main text. Abbreviations: UCH (Universidad de Chile), PUC (Pontificia Universidad Católica de Chile).*

Fig. 4. Claudio Barros and Juan Fernández. (A) *Claudio Barros (right) celebrating his PhD with Colin R. Austin (middle) and other lab members at the University of Tulane, 1968. Barros initiated his studies of developmental biology in the Austin lab.* **(B)** *Juan Fernández (right) with Gunther Stent (left) and Nancy Olea (middle) at the Annual Meeting of the Chilean Biology Society, 1990. Juan Fernández initiated his studies of developmental biology with Gunther Stent at the University of California in Berkley.* **(C)** *Claudio Barros with his mentor and friend Luis Izquierdo, circa 1990s.* **(D)** *Claudio Barros, Juan Fernández and Luis Izquierdo with developmental biology colleagues at the first Annual Meeting of the Chilean Society for Cell Biology in Jahuel, Chile, 1987. From Left to right: Carlos Doggenweiler, Roxana Pey, Soledad Sepúlveda, Nancy Olea, María Soledad Fernández, Luis Izquierdo, Arnold I. Caplan (Case Western Reserve University), Claudio Barros, Mireya Fernández, Juan Fernández.*

entific contributions from his research at the Faculty of Sciences are the finding of cell-cell contact-dependent spatial order and supra-cellular cytoskeletal connections during compaction of the early blastomeres. Through manipulations, Luis Izquierdo also explored the regulative capacity of early mammalian embryos to propose the hypothesis of a developmental clock that specifies the ordered expression of genes or processing of their products (see a summary of his research in (Barros and Schatten, 1993; Izquierdo, 1991)). For Luis Izquierdo, microscopy was a fundamental approach to investigate developmental biology. He was the first to use electron microscopy to study developmental biology in Chile and later, which can be considered his last contribution to Chilean science, he introduced the first confocal microscope to the country (Supplementary Fig. S1).

Luis Izquierdo mentored a large number of students and collaborators during the almost forty years of his scientific career. In all of them, he left an indelible mark regardless of the different destinies of their future careers. Remarkably, many of his pupils followed successful careers on applied aspects of reproductive biology and became part of human reproduction centres in Chile, Argentina and Peru[4]. Others derived in biotechnology, pathology, university duties, or continued in developmental biology for a variable time. Among the latter, Claudio Barros, his first student at the PUC (see below) and Roberto Mayor, a PhD student from the Faculty of Sciences of the UCH (Concha, this issue) were the disciples that best expressed in their successful scientific careers the vision and persistence in basic research that Luis Izquierdo always defended and promoted.

Early growth of the discipline (late 1960s - early 1990s)

After the first drive led by Luis Izquierdo, two scientists joined the cause of developmental biology in Chile. Claudio Barros (Fig. 1B) and Juan Fernández (Fig. 1C), since the late 1960s and 1970s, respectively, contributed with unique and complementary facets to the early growth of the discipline. The number of students and researchers interested in developmental biology expanded to generate a critical mass eager of interactions. The developmental biology community found the first niche for scientific exchange at the Chilean Biology Society, interacting actively with the reproductive biology community. In this context, the idea of organising the first international course of developmental biology emerged

[4]After training with Luis Izquierdo, Blanca Fuentealba, Luis Roblero and Maria Helena Ortiz moved to the reproductive biology field at the PUC with Hector Croxatto and Fernando Zegers, and became part of the Chilean Institute of Reproductive Biology (ICMER). Maria Soledad Sepúlveda became director of assisted reproduction labs in Chile (Centro de Estudios Reproductivos, CER) and Peru (PRANOR). Ariel Ahumada became director of PROCREARTE, the first network of reproductive medicine in Argentina.

TABLE 1

INTERNATIONAL COURSES, MEETINGS, SYMPOSIA AND OPEN LECTURES ON DEVELOPMENTAL BIOLOGY HELD IN CHILE

Year	Name	Type	Organisers	Place
1987	Development and the cytoskeleton	Symposium	Juan Fernández	ChBS (La Serena)
1993	Imaging the cell during development and reproduction	Course & Symposium	Luis Izquierdo (#), Claudio Barros, Gerald Schatten, Enrique Dupré, Juan Fernández	Marine Biological Station, UCN (Coquimbo)
1999	The newest on developmental genetics	Course	Roberto Mayor, Miguel Allende	Faculty of Sciences, UCH (Santiago)
2001	Developmental genetics	Course & Symposium	Roberto Mayor, Miguel Allende	Faculty of Sciences, UCH (Santiago)
2003	First International meeting of the Latin American Society for Developmental Biology (LASDB)	Meeting	Roberto Mayor, Miguel Allende	Valle Nevado (Santiago)
2003	LASDB Practical course on developmental biology	Course	Roberto Mayor, Miguel Allende	Faculty of Sciences, UCH (Santiago)
2004, 2006	Genetic control of embryonic development	Course	Miguel Concha, Juan Larraín	Faculty of Medicine, UCH & Faculty of Biological Sciences, PUC (Santiago)
2005	Transgenesis in zebrafish and Medaka	Course	Miguel Allende, Miguel Concha	Faculty of Sciences & Faculty of Medicine, UCH (Santiago)
2007	In vivo 3D imaging: computational analysis of cell behaviour in developing embryos	Course	Miguel Concha, Steffen Härtel	Faculty of Medicine, UCH (Santiago)
2007	Embryonic stem cells as a model for mammalian development	Course & Symposium	Veronica Palma, Josh Brickman, Jenny Nichols, Meng Li	Faculty of Sciences, UCH (Santiago)
2008	From development to tissue regeneration	Symposium	Juan Larraín, Miguel Allende	Faculty of Biological Sciences, PUC (Santiago)
2010	Fifth International meeting of the LASDB	Meeting	Miguel Allende, Miguel Concha, Juan Larraín	Santa Cruz
2010	Concepts and model organisms in regenerative biology	Course	Miguel Allende, Ida Chow Richard Harland, Juan Larraín	Faculty of Biological Sciences, PUC (Santiago)
2010, 2012, 2014, 2018, 2020	Practical course on developmental biology -Quintay	Course & Symposium	Roberto Mayor, Ariel Reyes, Alfredo Molina, John Ewer, Kathleen Whitlock, Fernando Faunes	Centre for Marine Biology Research CIMARQ (Quintay)
2013, 2014, 2016, 2019	Optics, Forces & Development	Course	Miguel Concha, Steffen Härtel, Mauricio Cerda, Rodrigo Soto	Faculty of Medicine, UCH (Santiago)
2013	Advanced microscopy and Image processing	Symposium	Steffen Härtel, Miguel Concha	Faculty of Medicine, UCH (Santiago)
2013	Getting in shape: visualization and manipulation of organismal morphogenesis	Course	Jochen Wittbrodt, Miguel Allende	Heidelberg Centre for Latin America and Faculty of Sciences, UCH (Santiago)
2014, 2015, 2017, 2018	RiBiD meeting of developmental biology researchers	Meeting	Fernando Faunes, Carlos Oliva, Esteban Contreras, Gonzalo Olivares, Rodrigo Morales, Natalia Sánchez, Patricio Olguín	PUC (2014), Faculty of Sciences UCH (2015), Faculty of Medicine UCH (2017, 2018) (Santiago)
2014	International practical course of LAZEN	Course	Kathleen Whitlock	UV (Valparaiso)
2014	Origin of animal form in development and evolution	Open Lecture	Miguel Concha	Former Congress Building (Santiago)
2014	Visualization and manipulation of signals and forces in developing tissues	Symposium	Miguel Concha, Hernán López-Schier, Carl-Philipp Heisenberg	Telefónica OpenFuture Branch of UrbanStation, (Santiago)
2015	Hedgehog workshop Santiago 2015	Symposium	Verónica Palma	Faculty of Sciences, UCH (Santiago)
2017	First Chilean-German workshop on mural cell biology	Symposium	Julio Amigo	Faculty of Biological Sciences, PUC (Santiago)
2019	Manipulating the origin of human life. What are we up to?	Open Lecture	Miguel Concha	Former Congress Building (Santiago)
2019	Exploring new tools to understand development using organ culture	Symposium	Marcia Gaete, Oscar Inzunza	PUC (Santiago)
2019	EMBO Workshop Bridging cell and tissue mechanics to fate specification in development	Symposium	Miguel Concha, Carl-Philipp Heisenberg, Anna-Katerina Hadjantonakis, Rodrigo Soto	Faculty of Physics and Mathematics, UCH (Santiago)

(#) Luis Izquierdo was one of the main organisers although he died one month before the course was held.

Abbreviations: ChBS (Chilean Biology Society); ChSCB (Chilean Society for Cell Biology); LASDB (Latin American Society for Developmental Biology); LAZEN (Latin American Zebrafish Network); PUC (Pontificia Universidad Católica de Chile); UCH (Universidad de Chile); UCN (Universidad Católica del Norte); UV (Universidad de Valparaíso).

and after years of preparation became a reality in January 1993. Sadly, this was only one month after the death of Luis Izquierdo, a principal planner and promoter of this course (see below and chronology in Fig. 3).

Claudio Barros: a basic researcher at the interface of development and reproduction

When Luis Izquierdo was Professor at the PUC, between 1955 and 1964, he trained several medical students and one of his first pupils later shined on his own. Claudio Barros was interested in the very early stages of life when the sperm meets the oocyte and powered by Luis Izquierdo travelled to the University of Tulane in the US to do a PhD with Colin Russel Austin, a world leader in mammalian fertilisation (Fig. 4A) (Barros, 1980). In Tulane, he published his first papers on developmental biology, including the famous work describing that the mammalian oocyte and the spermatozoon fuse together side by side (Barros *et al.*, 1967). Claudio Barros returned to Chile in 1968 and established his lab in the Biology Department at the Medical School of the PUC with funds from the Rockefeller Foundation (The Rockefeller Foundation, 1968). After the foundation of the Institute of Biological Sciences of the PUC, he became head of the Embryology Laboratory (Barros, 1980). His rigorous mind and hard-working attitude drove him to become a world leader in the problem of sperm biology and particularly in the process of acrosome reaction (Moreno and Santos, 2011; Yunes, 2009). He reached an impressive number of scientific publications, including his first developmental biology paper from Chile with Ryuzo Yanaguimachi (Barros and Yanagimachi, 1971). He also trained an abundant offspring of young investigators while holding several distinctions and memberships, and playing directive roles in various scientific societies[5]. He died in 2008 at the age of 72

[5]Claudio Barros was president of the Chilean Society for Cell Biology, the Chilean Society of Reproduction and Development and the Iberoamerican Society for Cell Biology, and vice-president of the International Federation of Cell Biology.

Fig. 5. Pilot practical course on Developmental Biology, Coquimbo (1989). *The course "Developmental and reproductive biology of marine organisms" was held at the marine station of the* Universidad Católica del Norte *(UCN), Campus Coquimbo (north Chile), on January 14-28, 1989. This was a pilot for the actual course held in the same place four years later in 1993. It involved mostly students and scientific staff associated with the labs of the organisers: Luis Izquierdo, Claudio Barros and Juan Fernández (from Santiago), and Gilda Bellolio and Enrique Dupré (from UCN).* **(1)** *Luis Izquierdo;* **(2)** *Rodrigo Fernández (Undergraduate student, Fernández lab);* **(3)** *Gilda Bellolio (Professor, UCN);* **(4)** *Horacio Vega (PhD student, Izquierdo lab);* **(5)** *unidentified;* **(6)** *Ricardo Moreno (Biologist, Barros lab);* **(7)** *Claudio Pérez (Biologist, Barros lab);* **(8)** *Daniel Moraga (PhD student, Izquierdo lab);* **(9)** *Marina Ríos (Master student, Fernández lab);* **(10)** *Victor Cussac (Visiting Professor, University of Comahue, Argentina);* **(11)** *unidentified;* **(12)** *Soledad Sepúlveda (PhD student, Izquierdo lab);* **(13)** *Magdalena Rocco (Instructor PUC, Barros lab);* **(14)** *Carlos Doggenweiller (Professor, UCH, Izquierdo lab);* **(15)** *Roberto Mayor (PhD student, Izquierdo lab);* **(16)** *Enrique Dupré (Professor, UCN; also Master student Barros lab);* **(17)** *Claudio Barros;* **(18)** *Andrea Castro (Biology student PUC, Barros lab);* **(19)** *Luis Isla (Fishery Engineer, La Molina University, Peru);* **(20)** *Verónica Téllez (PhD student, Fernandez lab);* **(21)** *unidentified;* **(22)** *Roxana Pey (PhD student, Izquierdo lab);* **(23)** *Alejandra Mansilla (PhD student, Izquierdo lab);* **(24)** *Nibia Berois (Visiting Professor, Republic University of Uruguay);* **(25)** *Juan Fernández;* **(26)** *Karin Lohrmann (Professor, UCN);* **(27)** *Ariel Ahumada (PhD student, Izquierdo lab). Nancy Olea (Medical Technologist, Fernandez lab) also attended the course but is missing from the picture. For abbreviations, see p.1.*

(Moreno and Santos, 2011; Yunes, 2009).

As a scientist interested in the phenomenon of fertilisation, Claudio Barros placed himself at the interface of developmental and reproductive biology. From this unique position, he fostered the growth of developmental biology in Chile serving a (perhaps unintended) role of articulator with the reproductive biology community. Nonetheless, contrary to the more applied approach that dominated the field of reproductive biology, Claudio Barros always stood out for his unwavering interest in basic science. He demonstrated, as Luis Izquierdo did, that a systematic and coherent work in basic sciences can permeate to the professional field by providing a continuous flow of highly qualified trainees, which in this particular case helped to develop the field of human assisted reproduction in Chile and South America.

Juan Fernández: a neuroscientist converted to developmental biologist

The career of Juan Fernández as developmental biologist followed a path independent from that of Luis Izquierdo and Claudio Barros, although they shared many places and circumstances (Fig. 3). After graduating as a teacher of biology and chemistry at the UCH, Juan Fernández began a career as a neuroscientist with a robust structural perspective. At the PUC, he learnt electron microscopy and histochemistry with Juan de Dios Vial Correa and Isidore Gersch, respectively. Then, he did a PhD in Anatomy at the University of Wisconsin funded by a Rockefeller fellowship (The Rockefeller Foundation, 1964) to publish his first papers in the nervous system of the snail. Back in Chile in 1968, he was appointed at the Faculty of Veterinary of the UCH and then he moved to the Faculty of Sciences where he started working on the nervous system of the leech (Fernandez and Fernandez, 1974). However, in the mid-1970s, his focus of research shifted from neuroscience to developmental biology after visiting Gunther Stent at the University of California in Berkley (Fig. 4B). Gunther Stent was a pioneer scientist who helped to establish the modern discipline of molecular biology through his studies in bacterial viruses (Barondes, 2011; Stent, 1963). At the time, Gunther Stent had already made his first change of scientific direction from mo-

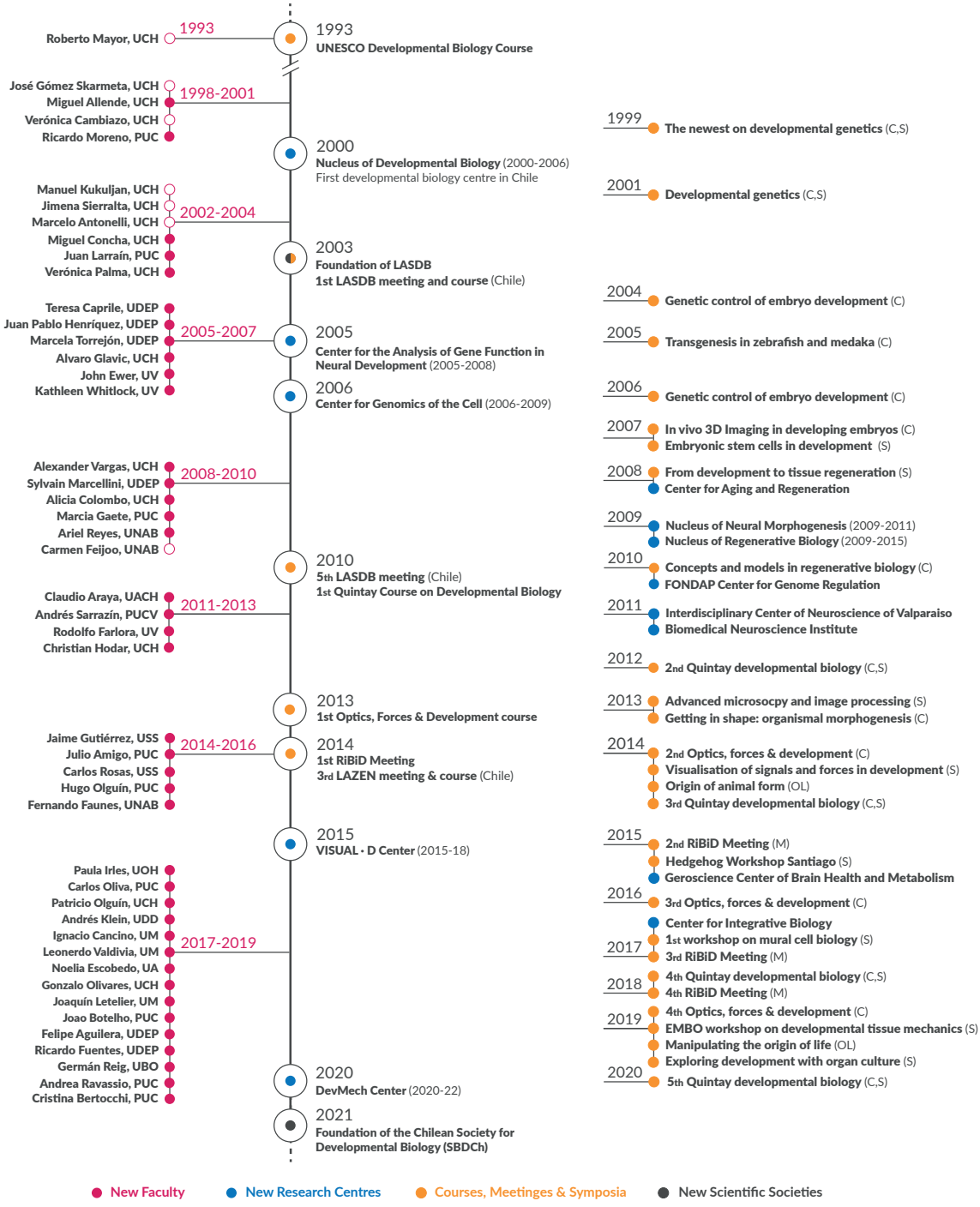

Fig. 6. Chronology of events for the last three decades of developmental biology in Chile. *The figure shows the events that marked the growth and diversification of developmental biology in Chile starting from 1993, indicted along a vertical temporal line that progresses from top to bottom. New faculty positions starting developmental biology research are shown as red circles on the left column. Open red circles correspond to cases in which faculty positions later left the country or changed the field of research. The central and right columns indicate the new centres (blue) and meetings/training activities (orange) of developmental biology taking place during this period (M: Meeting; S: Symposium; C: Course, OL: Open Lecture). The most relevant of these events together with the foundation of new developmental biology scientific societies (grey) are shown in the central column. The criteria to select these events are: new centres with a main focus on developmental biology (blue) and meeting/training activities with greatest impact and regularity in the developmental biology community (orange). More details are given in Table 1 (meetings/training activities), Table 2 (new centres with a central focus on developmental biology) and Supplementary Table 3 (new centres in which developmental biology is one of the main areas of research). Abbreviations: LASDB (Latin American Society for Developmental Biology), LAZEN (Latin American Zebrafish Network), PUC (Pontificia Universidad Católica de Chile), PUCV (Pontificia Universidad Católica de Valparaiso), RiBiD (Red de Investigadores en Biología del Desarrollo), UA (Universidad Autónoma de Chile), UACH (Universidad Austral de Chile), UBO (Universidad Bernardo O'Higgins), UCH (Universidad de Chile), UDD (Universidad del Desarrollo), UDEC (Universidad de Concepción), UNESCO (United Nations Educational, Scientific and Cultural Organization), UM (Universidad Mayor), UNAB (Universidad Andrés Bello), UOH (Universidad de O'Higgins), USS (Universidad San Sebastián), UV (Universidad de Valparaiso).*

lecular biology to neurosciences using the leech to study neural circuits and behaviour (Weisblat and Thompson, 2008). Being users of the leech to address questions of neuroscience, they both experienced a similar turn in their scientific interest towards developmental biology, sharing their first publication in this field (Barondes, 2011; Fernandez and Stent, 1980). Juan Fernández started studying the cytoplasmic movements that set the ovoplasmic domains of the zygote in the leech with a strong focus on the role of the cytoskeleton. In this context, he organised in 1987 a symposium on development and the cytoskeleton where he invited Gerald Schatten from the University of Wisconsin and Bill Jeffery from University of California. Both investigators would later play an essential role in the organisation the first international course of developmental biology in Chile (see below).

Juan Fernández was scientifically very rigorous and skilful in the techniques and worked with few long-lasting projects that often took years before publication. He was passionate about science and had an active involvement in the teaching of developmental biology at the Faculty of Sciences, where he helped to keep the spirit of the discipline alive after the death of Luis Izquierdo. Juan Fernández gave excellent lectures and became famous for his use of chalk and a blackboard to masterfully and graphically explain scientific concepts, demonstrating his in-depth knowledge and drawing talent. He died in 2018 at the age of 87, one day after giving one of his developmental biology classes without knowing it would be the last.

Interactions and early organisation of the developmental biology community

Researchers in the developmental biology field first presented their work at the annual meetings of the Chilean Biology Society. This society was created in 1928 influenced by a group of European scientists who infiltrated a modern view of biology in the country[6]. In the beginning, the Biology Society grouped all the biological research in the country, and within this context, different specialities of biology emerged. In many cases, they became sections of the society, and then, as the critical mass of researchers increased, they transformed into independent societies[7]. The developmental biology community followed that trend, although with some important distinctions. It started in the 1960s as a tiny community that represented about 1% of the total abstracts presented at the Biology Society. In the 1970s, this number doubled to become around 3% of all abstracts. Subsequently, in the 1980s exhibited a 3-4 fold increase (Supplementary Table S1). Such increase of abstract presentations paralleled the growth of the entire biology community in Chile. It also reflected the consolidation of the labs of Luis Izquierdo, Claudio Barros and Juan Fernández, and the emergence of new researchers addressing questions of developmental biology in the country (see footnote[8] and Supplementary Table S2 for a list of all researchers).

In the 1970s and 1980s, the developmental biology community interacted strongly with the reproductive biology community promoted by their leaders Luis Izquierdo (from development), Eduardo Bustos-Obregón (from reproduction) and Claudio Barros (at the interface of development and reproduction, also playing an articulating role between the two communities)[9]. In 1978, the Reproduction and Development section was created at the Chilean Biology Society under the direction of Claudio Barros (Ureta, 1978). This section had a dominant representation of reproductive biology as revealed by the number of abstracts presented at the Biology Society (70% of reproduction and 30% of development) (Supplementary Table S1). Over time, the section evolved to form the Society of Reproduction and Development led by Eduardo Bustos-Obregón and Claudio Barros (Rivas *et al*., 2014), further strengthening the dominant status of the reproductive biology community. Indeed, except for Claudio Barros, who was actively involved in the new society, the other leaders of developmental biology including Luis Izquierdo and Juan Fernández only had marginal participation (if any) at the annual meetings of the Society of Reproduction and Development (Supplementary Table S1). The reason for this separation probably resided in the different questions and approaches of the development and reproduction fields at that time. In particular, the emergence of molecular and genetic methods in the study of embryology placed the developmental biology field closer to other experimental disciplines like molecular and cell

[6]The French neuroscientist Louis Édouard Lapicque raised the need to create a society that brings together the research carried out in Chile, and this idea materialised shortly in 1927 with the foundation of the Biology Society in Concepción by Alejandro Lipschutz. The establishment in Chile of the French researcher Eugène Wollman, who had been a professor at the Pasteur Institute in Paris and was related to the Societé de Biologie from Paris, represented the impetus to start the Biology Society in Santiago, as a subsidiary of the Parisian society. The board of directors of the Biology Society was chaired by Gustavo Monckeberg and had Eduardo Cruz-Coke as vice president and Eugène Wollman as director (SBCH, 2019).

[7]Examples of societies that emerged from sections of the Chilean Biology Society are the Ecological Society, Society for Cell Biology, Society of Reproduction and Development, Botanic Society, and Society of Physiological Sciences.

[8]Among them, a group of investigators studied fertilisation in marine organisms at the UCN (Gilda Bellolio, Karin Lohrmann and Enrique Dupré) and UDEC (Maria Imschenetzky and Marcia Puchi). At the UACH, Boris Jorquera studied limb development in the frog and chick. Others, at the Faculty of Medicine of the UCH, used a descriptive morphological approach to study odontogenesis in lizards (David Lemus), maxillofacial malformations in mouse (Maria Angélica Montenegro) and the ultrastructure of the early human embryo (Jaime Pereda). Jaime Pereda, in particular, collaborated with prominent figures of the human reproduction field such as Héctor Croxatto from the PUC (Pereda and Croxatto, 1978) and Pietro Motta from the University La Sapienza, Rome (Pereda and Motta, 1991). He also gathered the most significant sample of human embryos and foetuses of Latin America that today form part of a dedicated museum. Finally, investigators from different universities used ontogenic perspectives to understand better the structure or function of a particular organ or system. Examples include the ruminal (José Luis Arias from the UCH) and gastric (Cecilia Koenig and Monica Dabike from the PUC) epithelia, the circadian rhythm (María Josefa Serón-Jofré from the PUC) and the subcommissural organ and ependymal brain specialisations (Esteban Rodriguez from the UACH). The case of Esteban Rodriguez is worth noting as the use of an ontogenic perspective allowed him to change a paradigm about the origin of congenital hydrocephaly, making it not a simple "plumbing problem" but a developmental disorder that involves deficiencies in the neurogenic niche (Guerra et al., 2015).

[9]Claudio Barros and Luis Izquierdo had an excellent relationship (Fig. 4C) and this probably facilitated the interactions between the reproductive and developmental biology communities.

TABLE 2

RESEARCH CENTRES FUNDED BY THE CHILEAN GOVERNMENT WITH A MAIN FOCUS ON DEVELOPMENTAL BIOLOGY

Years	Name	Funds (#)	Principal Investigators
2000-2006	Millennium Nucleus of Developmental Biology	MSI	Roberto Mayor (director). Miguel Allende, Motoe Kato, Ruby Valdivia, (period 2000-2003) Miguel Allende (director). Juan Larrain, Roberto Mayor. Young inv: Marcello Antonelli, Manuel Aybar, Alvaro Glavic, Ricardo Moreno, Veronica Palma, Ariel Reyes, (period 2004-2006)
2005-2008	Research Ring for the Analysis of Gene Function in Neural Development	PBCT	Miguel Concha (director). Steffen Härtel, Manuel Kukuljan, Jimena Sierralta
2006-2009	Millennium Nucleus Center for Genomics of the Cell	MSI	Miguel Allende (director). Verónica Cambiazo, John Ewer, Alvaro Glavic, Veronica Palma, Kathleen Whitlock
2015-2018	Research Ring for the Visualisation and Manipulation of Signals and Forces in Developing Tissues (VISUAL·D)	PIA	Miguel Concha (director). Julio Amigo, Steffen Härtel. Associate invest: Mauricio Cerda, Germán Reig, Rodrigo Soto
2020-2022	Research Ring for the Multiscale mechanics and self-organizing processes in developing systems (DevMech)	PIA	Andrea Ravassio (director). Cristina Bertocchi, Mauricio Cerda, Miguel Concha, Tom Rudge

(#) Chilean Funding Programs: MSI (Millennium Science Initiative, since 1998); PBCT (Bicentennial Program of Science and Technology, since 2004); PIA (Program of Associative Research, since 2009). With the exception of MSI, which was first part of the Ministry of Planification and then the Ministry of Economy, the other programs were part of the National Commission for Scientific and Technological Research (CONICYT) from the Ministry of Education. Since 2020, all these funding programs became centralised in the National Agency for Research and Development (ANID) from the newly formed Ministry of Science, Technology, Knowledge and Innovation.

biology. As the critical mass of developmental biologists was insufficient to generate a society, the community searched for additional niches to present their research and found one at the Chilean Society for Cell Biology (Fig. 4D; Supplementary Table S1), which was founded in 1987, a year before the Society of Reproduction and Development (Fig. 3).

The first international course on developmental biology in Chile

A milestone in the history of developmental biology in Chile was the organisation by its community of the first international course in the discipline (Fig. 3). However, not only the course itself was so important but also the circumstances surrounding its creation and execution. The course was conceived in the context of the 1987 annual meeting of the Chilean Biology Society when Gerald Schatten and Bill Jeffery attended a symposium on development and the cytoskeleton organised by Juan Fernández. Bill Jeffery had been co-director of the famous Embryology Course at the Marine Biological Laboratory in Woods Hole (1983-1987). The idea of organising a similar course in Chile emerged in conversations between Bill Jeffery, Gerald Schatten, Luis Izquierdo, Juan Fernández and Claudio Barros. It was though as taking place in a marine biological station with a focus on development and microscopy, combining lectures with hands-on practical sessions in different model organisms.

The course setup imposed several challenges concerning the availability of scientific equipment and the procurement and handling of biological material. The ability to solve them reflected the community's commitment, the friendship and cooperation among its members, especially between Luis Izquierdo and Claudio Barros (Fig. 4C), and the international support provided by Bill Jeffery and Gerald Schatten. To prepare the conditions, they carried out experimental versions. The first trial was in 1988 at a marine station in Puerto Montt (south Chile) followed by a second trial in 1989 at the marine biological station of the UCN in Coquimbo (north Chile). The latter worked as a mock of the actual course. It involved the local organisers and students and scientific staff associated with the labs of Luis Izquierdo, Claudio Barros and Juan Fernández (Fig. 5). They travelled several hours by car from Santiago carrying equipment to develop methodological work on practical experiences using embryos of local marine species, many of which were unfamiliar to them (Mayor, this issue). Four years later, in 1993, the international course was successfully held under the name "Imaging the Cell during Development and Reproduction" with strong support from the UNESCO. Twenty students, mostly from Latin America and the US, attended the course that had a prominent list of national and international teachers (Supplementary Fig. S2). Regrettably, Luis Izquierdo, who was one of the key creators of the course, could not attend as he died only one month before. To honour his contribution to the course and the developmental biology discipline in Chile, Claudio Barros and Gerald Schatten organised a special issue in the journal Biological Research of the Chilean Biology Society. This issue included a tribute to him by Claudio Barros and Gerald Schatten and a collection of scientific papers mostly from participants of the course (Biological Research, Volume 26, 1993). These two events, the UNESCO international course and the death of Luis Izquierdo marked the end of an era in the history of developmental biology in Chile.

Creating new poles of developmental biology research (early 1990s - late 2000s)

From the early 1990s and until the late 2000s, a small collection of young investigators arrived in Chile after postdoctoral training in Europe and the US. They created new poles of developmental biology research with distinctive trademarks at the UCH, PUC, *Universidad de Valparaíso* (UV) and *Universidad de Concepción* (UDEC). Research areas in developmental genetics, cellular and molecular morphogenesis, regenerative biology, stem cells and evo-devo, to name some, appeared for the first time. The Chilean Society for Cell Biology consolidated as the leading society context for the diffusion and exchange of developmental biology research in the country. The impetus of the new generation of young developmental biologists produced a stimulating environment for the training of students, and developmental biology reached a significant impact in Chile and Latin America through the organisation of local and international courses and symposia in different topics of the discipline. In parallel, and taking advantage of governmental grant initiatives that commenced promoting associative research in Chile, the first research centres with a focus on developmental biology appeared in Chile, fostering the discipline to an unprecedented level (see a chronology of events in Fig. 6).

Keeping the tradition of developmental biology at the Faculty of Sciences of the University of Chile (UCH)

The death of Luis Izquierdo was a hard blow for the developmental biology community in Chile, especially for the Faculty of Sciences of the UCH. He was not only a community leader but also the head of a productive research group that investigated unique developmental biology questions in the country. Regrettably, the research program of mammalian preimplantation development ended after the death of Luis Izquierdo. His lab space at the Faculty of Sciences was inherited in 1993 by Roberto Mayor, a former PhD student of Luis Izquierdo returning from a postdoc with Mike Sargent at the National Institute for Medical Research in the UK. In Chile, Roberto Mayor set up a molecular developmental biology lab using *Xenopus*, and later also zebrafish, dedicating almost ten years to the study of neural crest induction before moving back to the UK in 2004 (Concha this issue). During this period, he promoted the faculty appointments of young investigators that strengthened the core of developmental biology at the Faculty of Sciences. The first, Jose Luis Gómez-Skarmeta, carried out a three-year stay at UCH after which returned to his country of origin Spain (1998-2000). Coincidentally, Miguel Allende arrived at the Faculty of Sciences after a postdoc with Nancy Hopkins at the Massachusetts Institute of Technology, where he was part of an insertional mutagenesis screen in zebrafish (Allende *et al.*, 1996; Gaiano *et al.*, 1996). He introduced the zebrafish model in Chile (and in South America) and based on his expertise in developmental genetics opened a research line in neural development that later evolved to the study of lateral line development and regeneration as well as various other developmental biology topics (e.g. Hernandez *et al.*, 2007; Villegas *et al.*, 2012). Roberto Mayor and Miguel Allende were both very active in the training of students. They organised a series of international courses and symposia with a great impact throughout Latin America (Table 1). In one of these courses, the idea of generating a Latin American network of developmental biologists emerged, which later resulted in the foundation of the Latin American Society for Developmental

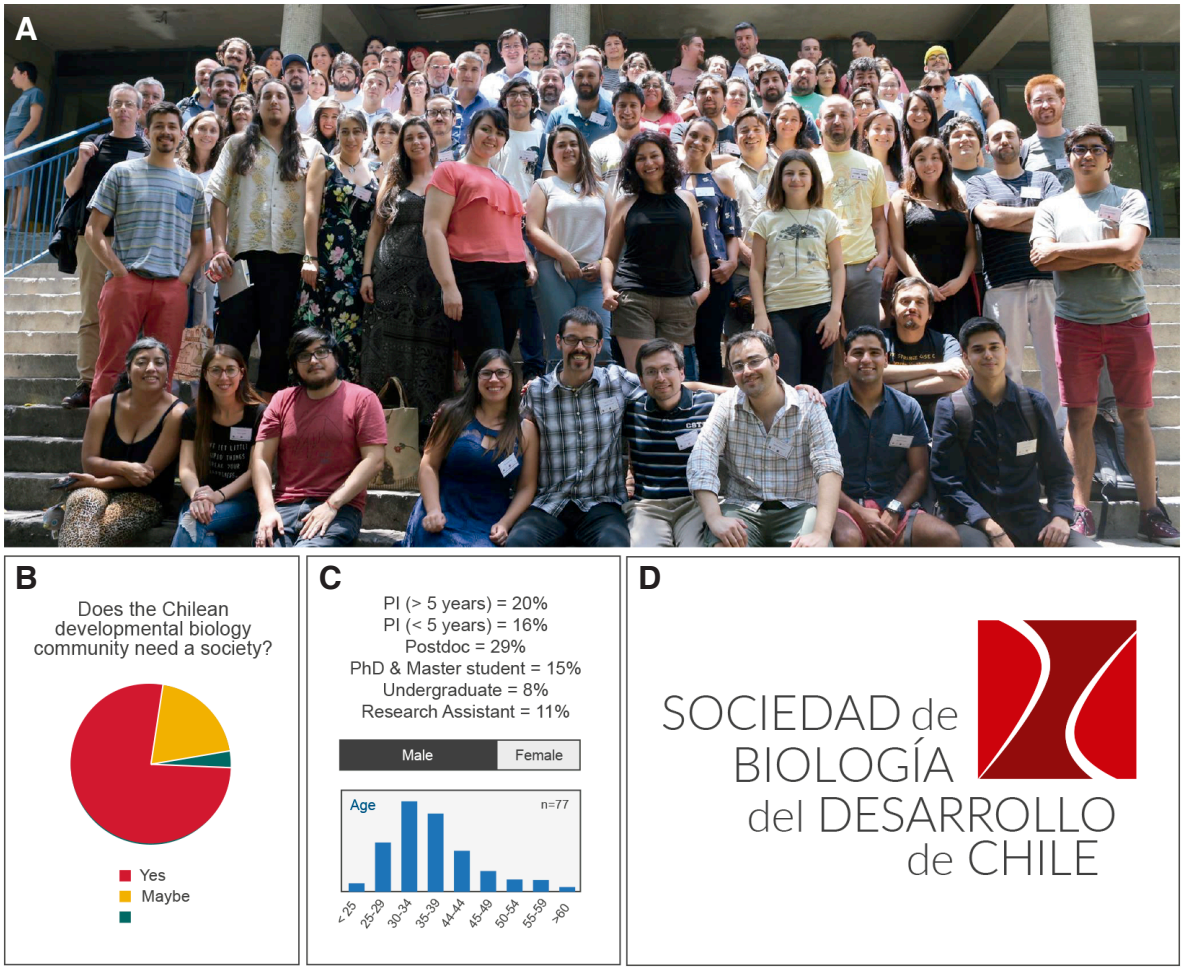

Fig. 7. Building the Chilean Society for Developmental Biology. *Events that lead to the creation of the Chilean Society for Developmental Biology (SBDCh).* **(A)** *The RiBiD meetings opened the way to imagine new forms of community organisation. The photo shows the attendants of the fourth RiBiD meeting at the Faculty of Medicine of the UCH, 2018. Organisers of the RiBiD meeting are shown in Table 1.* **(B)** *A survey was conducted in the Chilean developmental biology community in 2018. A key question was if the Chilean developmental biology community needed to organise as a society. The overwhelming majority supported the creation of the Chilean Society for Developmental Biology (SBDCh).* **(C)** *The developmental biologists that answered the survey were from different stages of their career and gender, and with a high representation of young investigators (age distribution histogram at the bottom).* **(D)** *Logo of the SBDCh created after a community contest. Claudio Araya from the UACH won the contest (D).*

Biology (LASDB) (Wappner and Zurita, this issue).

In 2000, Roberto Mayor and Miguel Allende formed the Millennium Nucleus of Developmental Biology together with Ruby Valdivia and Motoe Kato, two scientists from the Faculty of Dentistry of the UCH with experience in mutagenesis and genotoxicity (Table 2). It was the first associative research initiative with a focus on developmental biology in Chile. After Roberto Mayor moved back to the UK in 2004 (Concha, this issue) the positions left by him and Jose Luis Gómez-Skarmeta were replaced by returning former PhD students of Roberto Mayor. In 2003, Verónica Palma set up a lab in Hedgehog-Gli signalling, stems cells and forebrain development using chick and mouse after a postdoc with Ariel Ruiz i Altaba at the Skirball Institute in New York (e.g. Edwards *et al.*, 2014; Palma *et al.*, 2005). Then, in 2005, Alvaro Glavic started a research project in the control of growth and stress adaptation in *Drosophila* after a postdoc with Antonio Garcia-Bellido and José Felix de Celis at the Severo Ochoa Center of Molecular Biology in Spain (e.g. Ibar *et al.*, 2013). Miguel Allende together with the new faculty of development biologists and investigators from the National Institute of Agricultural Technology (INTA) and the UV (see below) formed in 2006 a new Millennium Nucleus with a strong focus on genetics and genomics, the Center for Genomics of the Cell (Table 2).

Juan Fernández continued his investigation of ovoplasmic segregation. However, he switched his research from the leech to zebrafish due to the advantages this model offered for *in vivo* imaging. Juan Fernández also played an active role in the teaching of developmental biology at the Faculty of Sciences coordinating until 2010 the traditional undergraduate course in developmental biology inherited from Luis Izquierdo. After that, he shared the coordination of the course with Verónica Palma and other members of the renewed faculty of developmental biologists.

Breaking the tradition of descriptive embryology at the Faculty of Medicine of the University of Chile (UCH)

The tradition of descriptive embryology and comparative anatomy was dominant at the Faculty of Medicine of the UCH until the late 1990s. However, this condition changed with the rise of molecular biology and the profound reorganisation that the Faculty of Medicine suffered during the creation of the Institute of Biomedical Sciences in 1997. As a consequence, many morphologists emigrated to other institutions and new faculty positions brought more modern views of developmental biology. Among them was Miguel Concha, a young medical doctor trained as a zebrafish developmental biologist in the UK with Richard Adams at Oxford University (Concha and Adams, 1998) and Stephen Wilson at University College London (Concha *et al.*, 2000). In 2002, he set up a zebrafish lab to investigate how animals generate form during ontogeny and evolution from two different perspectives. Based on his expertise on *in vivo* imaging and neural development he approached the cellular mechanisms underlying tissue morphogenesis in the early embryo (e.g. Oteiza *et al.*, 2008; Reig *et al.*, 2017) and studied left-right asymmetry in the brain from a comparative evo-devo perspective (e.g. Concha *et al.*, 2012). In 2005, Miguel Concha associated with Jimena Sierralta and Manuel Kukuljan to create the Centre for the Analysis of Gene Function in Neural Development (Table 2). Jimena Sierralta trained initially as a *Drosophila* molecular biologist at the University of California and then began to study the role of the scaffolding protein Dlg in neuronal development and searching for new genes involved in terminal axonal development (e.g. Mendoza-Topaz *et al.*, 2008). Manuel Kukuljan came from the channel biophysics field and started investigating the transcriptional regulation of the neuronal phenotype with a focus on ionic channels, first in *Xenopus* and later moving to the mouse cerebral cortex (e.g. Fuentes *et al.*, 2012). At that time, Steffen Härtel, a physicist with expertise unique in the country on microscopy and image analysis joined the new centre and set up a lab that merged with the lab of Miguel Concha. They both started a prosperous partnership that led to the creation of a Latin American hotspot for *in vivo* morphogenesis, microscopic imaging and quantitative developmental biology, organising a series of courses and symposia on these topics with a focus on Latin American students. Among them, the course "Optics, Forces & Development" became a trademark and a persistent training activity in the region (Table 1). The original idea of the developmental biology centre led by Miguel Concha evolved to give rise in 2009 to a new Millennium Nucleus with a focus on neural morphogenesis and cell biology (Supplementary Table S3).

The arrival of a new generation of scientists served to permeate modern concepts to the undergraduate and postgraduate teaching of developmental biology at the Faculty of Medicine of the UCH. As part of this process, Miguel Concha associated with Juan Larraín from the PUC (see below) to organise in 2004 and 2006 the course "Genetic Control of Embryo Development" (Fig. 7 and Table 3). This course was a unique cross-university training initiative that expanded the capacities of developmental biology training in the country, covering a wide range of topics in developmental biology from fertilisation to organogenesis, with an extensive list of teachers from Chile and abroad.

Moving beyond fertilisation at the Faculty of Biological Sciences of the Pontifical Catholic University of Chile (PUC)

Fertilisation for a long time was the main focus of research in developmental biology at the Faculty of Biological Sciences of the PUC. First led by Claudio Barros, who remained active until the early 2000s, and then by Ricardo Moreno, a former PhD student of Claudio Barros who was recruited in 2000 to continue research on this topic (e.g. Torres-Fuentes *et al.*, 2015). But a new research area of developmental biology started in 2002 with the arrival of Juan Larrain. He returned to Chile after a postdoc with Eddy De Robertis at the University of California, where he studied the molecular regulation of dorsoventral patterning in *Xenopus* gastrulation (Oelgeschlager *et al.*, 2000). Juan Larrain started a lab at the PUC with a distinct focus on molecular biology and biochemistry to study the function of proteoglycans in *Xenopus* development (e.g. Munoz *et al.*, 2006). After his arrival, he joined the core of investigators of the Millennium Nucleus of Developmental Biology led by Roberto Mayor and Miguel Allende (Table 2). During these years, he co-organised, together with Miguel Concha from the UCH, the course "Genetic Control of Embryo Development" (see above). This course was especially crucial for Juan Larrain and the developmental biology discipline at the PUC. Not only it was a seed of developmental biologists that later established labs at the PUC (see next section) but also the forerunner of a course in developmental biology that Juan Larrain set at the Faculty of Biological Sciences of the PUC from 2010. With time, the research of Juan Larrain shifted from

TABLE 3

DEVELOPMENTAL BIOLOGISTS WORKING IN CHILE AT THE YEAR 2020

City / University / Name	Topic	Models
VALPARAISO & VIÑA DEL MAR		
Universidad Andres Bello (UNAB) - Campus Viña del Mar		
Faculty of Life Sciences		
Fernando Faunes	Regulation and role of Lin28 in genetic control of metamorphosis	Drosophila, Xenopus (*X. laevis, X. tropicalis*)
Pontificia Universidad Católica de Valparaíso (PUCV)		
Chemistry Institute		
Andrés Sarrazin	Molecular and cellular mechanisms of patterning and growth in insect development; comparative developmental biology	Red flour beetle *(Tribolium castaneum)*, ringlegged earwig (*Euborellia annulipes*)
Universidad de Valparaiso (UV)		
Faculty of Sciences		
John Ewer	Circadian and endocrine control of Drosophila development	Drosophila
Rodolfo Farlora	Functional genomics; reproduction and development of aquatic organisms	Non-model aquatic organisms (e.g. copepoda, bivalva, fishes)
Kathleen Whitlock	Genetics and development of the nervous system; neuroendocrinology; behavior	Zebrafish
SANTIAGO		
Universidad Andres Bello (UNAB)		
Faculty of Life Sciences		
Ariel Reyes	Regulation of neural crest cell migration	Zebrafish
Universidad Bernardo O'Higgins (UBO)		
Integrative Centre of Biology and Applied Chemistry (CIBQA)		
German Reig	Cadherins and biomechanics in cell migration during epiboly; image processing and mathematical modelling of biological systems	Zebrafish, annual killifish (*Austrolebias nigripinnis)*
Universidad del Desarrollo (UDD)		
Faculty of Medicine		
Andres Klein	Systems genetics; neurogenetics; lysosomal storage diseases; Parkinson's disease	Drosophila, mouse
Universidad Mayor		
Centre for Integrative Biology		
Gonzalo Cancino	Cortical and neural development; neural stem cell and radial glial cells; neuronal migration; autism and neurodevelopmental disorders	Mouse, human iPSCs
Joaquín Letelier	Transcriptional regulation in development; gene regulation during visual system and fin formation	Zebrafish, medaka
Leonardo Valdivia	Genetic control of eye formation, eye growth and retina differentiation	Zebrafish
Pontificia Universidad Católica de Chile (PUC)		
Faculty of Biological Sciences		
Julio Amigo	Hematovascular development; hematopoiesis and angiogenesis	Zebrafish
Cristina Bertocchi	Cell-cell communication, interaction and sensing of mechanical stimuli in development and disease	In vitro approves with embryonic stem and transformed cells
João Botelho	Evo-devo of skeletal morphology; musculoskeletal and neuromuscular integration; limb development	Reptiles, mouse, zebra finch, chick, duck
Juan Larrain	Gastrulation; Wnt signalling; damage and regeneration of spinal cord and SNC; locomotive recovery	Xenopus (*X. laevis*), mouse
Ricardo Moreno	Gametogenesis and fertilization	Mouse, rat
Hugo Olguin	Muscle stem cell fate regulation; muscle regeneration; ubiquitin-proteasome system and control of differentiation	Mouse
Carlos Oliva	Nervous system development; axon guidance, cell migration, maintenance of the CNS	Drosophila
Faculty of Medicine		
Marcia Gaete	Craniofacial development; organogenesis	Xenopus (*X. laevis*), reptiles, mouse
Institute of Biological and Medical Engineering		
Andrea Ravassio	Multiscale mechanobiology of transforming systems such as embryonic development and cancer transformation	In vitro approves with embryonic stem and transformed cells
Universidad San Sebastián (USS)		
Faculty of Health Sciences		
Jaime Gutiérrez	Placental development and vascular remodeling	Mouse, human
Faculty of Medicine and Science		
Carlos Rosas	Cellular and molecular basis of normal and pathological angiogenesis	Chick
Universidad de Chile (UC)		
Faculty of Medicine		
Alicia Colombo	Craniofacial malformation and orofacial cleft development; brain asymmetry; biobanking and oncology	Zebrafish
Miguel Concha	Early development and patterning; cell-tissue morphogenesis; developmental biomechanics; brain asymmetry; neurodevelopment and disorders; evo-devo; aging	Zebrafish; medaka, annual killifish (*Austrolebias nigripinnis; Nothobranchius furzeri*), non-model teleosts
Patricio Olguin	Neural patterning; development of muscle-tendon interaction and organ shape; nervous system development and variation in health and disease	Drosophila, Xenopus (*X. laevis*)
Gonzalo Olivares	Alternative polyadenylation and cell fate decision in adult stem cells; genetic variation in nervous system development and its role on adult behaviour	Drosophila
Mariana Rojas	Effect of environmental conditions (hypoxia, nutrition, temperature) on morphogenesis in embryos and fry	Salmon *(Salmo Salar*)
Faculty of Sciences		
Miguel Allende	Zebrafish developmental genetics; organ and tissue regeneration; innate immunity; bacterial infection models; xenotransplantation; toxicology; genomics of life in extreme or variable habitats	Zebrafish, killifish (*Orestias ascotanensis, Austrolebias charrua*)

TABLE 3 (CONTINUED)

DEVELOPMENTAL BIOLOGISTS WORKING IN CHILE AT THE YEAR 2020

Alvaro Glavic	Growth control and stress adaptation; Drosophila genetics; protein synthesis and metabolism; functional genomics	Drosophila
Veronica Palma	Shh/Gli signalling in neural stem cells; netrins as non-classic angiogenic molecules; human iPSC as a model for defective developmental neurological phenotypes; mesenchymal stem cells as therapeutic agents; intestinal stem cell behavior in metabolic homoeostasis control	Chick, mouse, human iPSC
Alexander Vargas	Paleontology & evo-devo; evo-devo of the Dinosaur-Bird transition	Zebrafish, Xenopus, reptiles, chick, Chilean tinamou, zebra finch, budgerigar, mouse
Institute of Nutrition and Food Technology		
Cristian Hodar	Evolution of the dorso-ventral genetic network in dipteran species; genomic evolution as mechanism for adaptation to the extreme or flexible environment	Drosophila and other flies (*Musca domestica*)
RANCAGUA		
Universidad de O'Higgins (UOH)		
Institute of Agricultural and Veterinary Sciences		
Paula Irles	Comparative insect oogenesis; functional genomics in insect reproduction; cell signalling in in ovarian growth; hormonal signalling in insect reproduction	Earwig (*Euborellia annulipes*), Cockroach (*Blattella germanica*)
TALCA		
Universidad Autónoma de Chile (UA)		
Faculty of Health Sciences		
Noelia Escobedo	Lymphatic vasculature in development and diseases	Mouse
CONCEPCIÓN		
Universidad de Concepción (UDEC)		
Faculty of Biological Sciences		
Felipe Aguilera	Functional and comparative genomics to understand the evolution of biomineralization in animals	See urchin (*Tetrapygus niger*), Pacific Oyster (*Crassotrea gigas)*
Teresa Caprile	Axonal guidance; role of embryonic cerebrospinal fluid during early neurogenesis	Chick
Ricardo Fuentes	Early Development; phenomics; disease models and mechanisms	Zebrafish
Juan Pablo Henríquez	Signalling pathways in development maintenance and regeneration of the vertebrate neuromuscular junction	Xenopus *(X. laevis, X. tropicalis*) chick, mouse
Sylvain Marcellini	Skeletal development and bone regeneration; evolution of biomineralization in vertebrates; functional evolution of regulatory molecules such as transcription factors and enhancers	Xenopus *(X. tropicalis*)
Marcela Torrejón	Modulation of neural crest induction and migration by heterotrimeric G protein signalling	Xenopus *(X. laevis, X. tropicalis*)
VALDIVIA		
Universidad Austral de Chile (UACH)		
Faculty of Science		
Claudio Araya	Brain morphogenesis; cell polarity and adhesion; collective cell dynamics; quantitative live imaging	Zebrafish

developmental biology to regeneration in the spinal cord of *Xenopus* and mouse (e.g. Gaete *et al.*, 2012). In this context, he led a new Millennium Nucleus on Regenerative Biology and became principal investigator of the Center for Aging and Regeneration at the PUC (Supplementary Table S3).

Starting developmental biology at the central coast of Chile

Developmental biology at Valparaiso on the central coast of Chile started in 2006 with the arrival of Kathleen Whitlock and John Ewer, two young investigators who moved to the UV in Chile from their established positions at Cornell University in the US. Kathleen Whitlock brought to Chile a project on the embryonic origin of gonadotropin-releasing hormone precursor cells in zebrafish that included the development of the olfactory sensory system (e.g. Cortes-Campos *et al.*, 2015; Torres-Paz and Whitlock, 2014). John Ewer, on the other hand, focused on the circadian and endocrine control of development using *Drosophila* as a model system (e.g. Mena *et al.*, 2016). Upon their arrival, Kathleen Whitlock and John Ewer joined the Millennium Nucleus Centre of Genome Regulation led by Miguel Allende, which helped them establish links with the developmental biology community in Chile. At the UV, Kathleen Whitlock and John Ewer contributed to the first Neuroscience Doctorate Program in Chile where they developed courses in genetics and development of the nervous system. Kathleen Whitlock also incorporated zebrafish and *Drosophila* as important model systems for understanding development in undergraduate courses of Developmental Biology. In Valparaiso, she also organised the 3rd meeting and course of the Latin American Zebrafish Network (LAZEN)[10] (Whitlock, 2014) and together with John Ewer, Roberto Mayor and developmental biologists from the *Universidad Andrés Bello* (UNAB) organised the Quintay Developmental Biology course (see below and Table 1).

A union of developmental biologists in Concepción

In the 2000s, a group of four young researchers created a diverse yet collaborative alliance of developmental biologists at the UDEC in Concepción. Not all of them trained primarily as developmental biologists, but instead, their research in other areas spontaneously converged into the discipline from different perspectives. In 2006, Marcela Torrejón started a project on the role of heterotrimeric G protein signalling in neural crest induction and migration in *Xenopus* (e.g. Toro-Tapia *et al.*, 2018) after a postdoc with Sigrid Reinsch at the NASA-Ames Research Center in the US. In the same year, Sylvain Marcellini arrived in Chile after a postdoc with Pat Simpson at the University of Cambridge in the

[10]LAZEN was created in 2010 as an AMSUD-Pasteur Network of zebrafish researchers from Argentina, Brazil, Chile and Uruguay, then expanded to other Latin American countries. LAZEN have organised bi-annual meetings and courses in 2010 (Montevideo, Uruguay), 2012 (Rosario Argentina), 2014 (Valparaiso, Chile), and 2016 (Cuernavaca, México). Website: http://lazen.fcien.edu.uy/home

UK where he studied how changes in gene enhancers can lead to morphological changes in evolution (Marcellini and Simpson, 2006). At Concepción, after a second postdoc with Martin Montecino, he set a lab studying the developmental evolution of bone tissue using *Xenopus* and a comparative approach (e.g. Cervantes-Diaz *et al*., 2017; Enault *et al*., 2015). In parallel, two investigators from other disciplines joined the group of developmental biologists as they began addressing ontogenic questions with an organismal perspective. Teresa Caprile investigated developmental aspects of axonal guidance in chick embryos (e.g. Stanic *et al*., 2016). At the same time, Juan Pablo Henríquez studied the signalling pathways in development, maintenance and regeneration of the vertebrate neuromuscular junction in *Xenopus* and mouse (e.g. Perez *et al*., 2019). In 2009, the four young faculty of developmental biologists created the Group of Processes in Developmental Biology (GDEP), an informal scientific association to potentiate the community of developmental biologists at the UDEC through sharing approaches, students, grants and publications. This group became involved in the PhD in Molecular and Cell Biology, organising postgraduate courses of developmental biology and renewing some aspects of the undergraduate teaching of the discipline.

Broadening the scope of developmental biology (late 2000s - today)

The most recent phase in the history of developmental biology in Chile involved the consolidation of existing poles of developmental biology research paralleled by the appearance of new initiatives and the recruitment of a substantial number of young investigators at different institutions of the country. The community of developmental biologists expanded in size and diversified its scope, also organising their first developmental biology meetings focused on young investigators, postdocs and students, fostering the sense of community and nurturing the need of formal organisation. Necessity then gave way to action and set the bases for the foundation of the Chilean Society for Developmental Biology (see a chronology of events in Fig. 6).

Evolution of research centres with focus on developmental biology

Research centres with a focus on developmental biology evolved in different ways during the last decade. Some centres created in the 2000s became more extended research initiatives containing a larger number of investigators and a broader scope where developmental biology was only one of the leading research areas. The Millennium Nucleus Center for Genomics of the Cell is one of these cases that gave way to the Center for Genome Regulation. Similarly, the Millennium Nucleus of Neural Morphogenesis later gave way to the Biomedical Neuroscience Institute (Supplementary Table S3). In other instances, developmental biologists became part of new large research centres holding a multidisciplinary approach (including developmental biology) into a particular topic. Examples of these cases are the Interdisciplinary Center of Neurosciences of Valparaiso, the Center for Aging and Regeneration, the Geroscience Center of Brain Health and Metabolism and the Center for Integrative Biology (Supplementary Table S3). Besides the evolution of large centres, two new associative research initiatives appeared in the last decade with a focus on emerging topics of developmental biology. In 2015, the VISUAL·D centre led by Miguel Concha from the UCH introduced the study of developmental tissue morphogenesis and mechanics from a multidisciplinary perspective centred on *in vivo* microscopy, image analysis and mathematical modelling (Table 2). In 2020, a new centre directed by Andrea Ravassio from the PUC made a step further to investigate the mechanobiology of embryonic development following a multiscale perspective that involved a team of developmental, cell, quantitative and theoretical biologists (Table 2).

Consolidation of international courses in developmental biology

The last decade has been very active in terms of opportunities for international training in developmental biology through dedicated courses and symposia organised in Chile (see list of events in Table 1 and a selection of posters of these events in Supplementary Fig. S3). Among them, two international courses with a focus on Latin American students addressing complementary aspects of developmental biology have stood out for their consistency and impact in the region. The "Quintay Developmental Biology" course was conceived by Roberto Mayor to train students in modern issues of developmental biology in various model organisms, inspired in previous courses he organised when he was in Chile in the late 1990s and early 2000s (Mayor, this issue). From his current faculty position at University College London in the the UK, Roberto Mayor associated with the UNAB and together with researchers from the UNAB and UV organise a developmental biology course at the CIMARQ Marine Biology Station in a bi-annual basis since 2010[11]. A second course, "Optics, Forces & Development", was conceived by Miguel Concha and Steffen Härtel as a first Latin American training initiative to approach developmental biology from a multidisciplinary perspective based on *in vivo* microscopy, image processing, quantitative biology and physical modelling. This course has been held at the Faculty of Medicine of the UCH in 2013, 2014, 2016 and 2019. So far, these two courses have trained over 200 students, postdocs and young investigators from all Latin America in the last decade (Mayor, this issue; CMD, 2019).

A wave of young developmental biologists establishes in the country

In contrast to the modest number of young researchers taking faculty positions at Chilean universities in the period 1993-2008 (in average, one position per year), more than twice as many positions per year have been filled by young developmental biologists in the last decade (Fig. 6). Geographically, most new recruitments involved universities located in the Santiago, followed by universities from the south and central coast of Chile. Notably, many of these positions corresponded to young investigators that did their PhD in developmental biology labs in Chile in the 2000s and after a postdoctoral training (often abroad) initiated their independent career as developmental biologists in Chile. A direct consequence of this extensive appointment has been the rapid expansion of the developmental biology community. The new appointments strengthen existing poles of developmental biology at universities in Santiago (PUC=7, UCH=5), Concepción (UDEC=2), Valparaíso (UV=1; PUCV=1) and Valdivia (UACH=1) (Fig. 6 and Table 3). They also introduced the discipline into places with no previous history in developmental biology. In

[11]Local organisers of the Quintay Developmental Biology course: Ariel Reyes, Alfredo Molina and Fernando Faunes from the UNAB; John Ewer and Kathleen Whitlock from the UV.

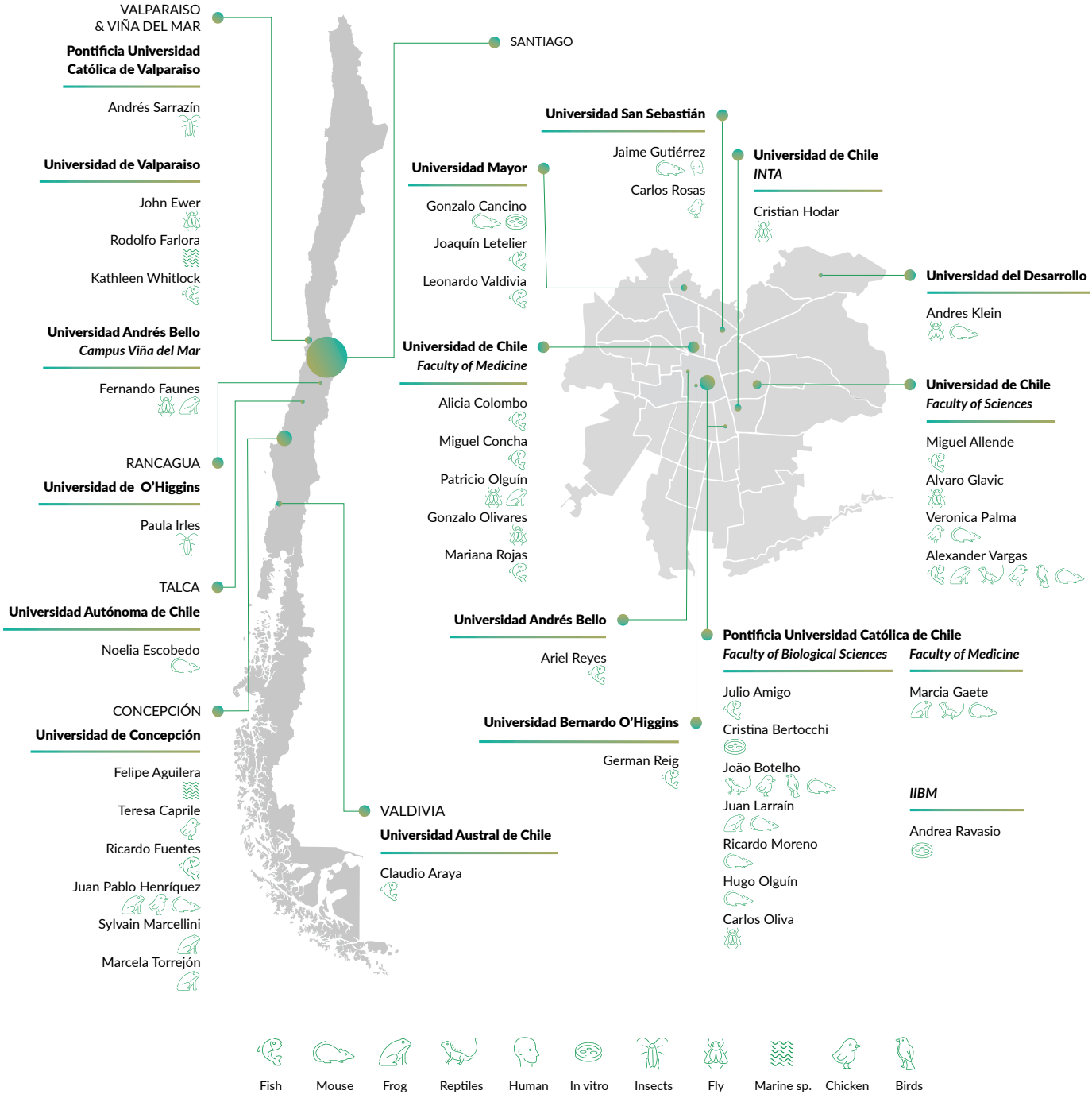

Fig. 8. Developmental biology researchers in Chile at the year 2020. *Geographical distribution of developmental biology researchers depicted in a map of Chile (left, north to the top) and in a map of the Chilean capital Santiago (right, north to the top). The main model organisms used for each researcher are indicated with an icon according to the nomenclature given at the bottom of the figure. Details of the research topics for each investigator are given in Table 3.*

particular, a large group of new faculty positions established at private universities that started investing resources in research to make their academic activities more complex and competitive at the national level (11 positions) (Fig. 6 and Table 3). The arrival of new young developmental biologists fostered a wide diversity of areas of research and introduced a variety of new vertebrate and invertebrate species to the study of developmental biology in the country (see details of topics and model organisms in Table 3 and Fig. 8).

Achieving a sense of community through developmental biology meetings

The arrival of young developmental biologists with a breath of new topics and approaches brought fresh air to a community that

had already experienced significant changes in their experimental focus since the 2000s. Part of the consolidated groups of developmental biologists deviated from the more classical questions of developmental biology into applied topics in the fields of regenerative biology, stem cells and genomics[12]. Others started adopting cellular approaches on developmental biology, including biomechanics or switched towards disease. Together, these transformations and the broad range of new topics brought by the new faculty positions diversified the scope of the discipline making it more complex. In this new context, the niche for scientific exchange at the annual meetings of the Chilean Society for Cell Biology no longer fulfilled the needs and interests of the evolving developmental biology community. Therefore, developmental biologists started searching for places to present and discuss their work at different Chilean scientific societies, but none represented them, and a feeling of non-belonging installed in the community. Driven by the interest of sharing their research, a group of young developmental biologists created in 2014 the Network of Researchers in Developmental Biology (RiBiD)[13]. Their idea was to have meetings where students, postdoc and young investigators could present and discuss their data in an informal environment, without the intervention of the principal investigators (Table 1). After a small startup, the idea of RiBiD took off in 2017 when they obtained financial support to organise proper meetings. The fourth meeting of 2018 gathered 100 attendants and resembled a scientific society meeting with oral presentations by students, postdocs and young investigators, which were combined with plenary lectures by international speakers (Fig. 7A). The success of the RiBiD meetings was fundamental in recovering a sense of community that had been lost long ago among developmental biologists.

Foundation of the Chilean Society for Developmental Biology

The RiBiD meetings unveiled the existence of a critical mass of developmental biologists keen of interactions and opened the way to imagine new forms of community organisation. But developmental biologists also wondered if the critical mass was sufficient to commit to the challenging task. In 2017, a group of developmental biologists took this matter into their hands and ideated a plan[14]. As a first step, they made a survey within the Chilean community of developmental biologists to learn about their size, diversity, interests and projections, and to objectify the need of organisation as a society. Seventy-seven developmental biologists from diverse stages of their career answered the survey and the results left no room for doubt. An overwhelming majority declared to be in favour of creating a society (Fig. 7B,C). After presenting the results of the survey at the fourth RiBiD meeting in January 2018, a group of volunteers committed to the task of making the necessary steps to create the Chilean Society for Developmental Biology (SBDCh)[15]. They organised a contest to generate the logo of the future society (Fig. 7D), as well as a plenary lecture by Kenneth Irvive to disseminate the idea of the future society in the context of the XXXII Annual Meeting of the Chilean Society for Cell Biology, and embarked in arduous discussions of the statutes of the future society. The foundational principles of the SBDCh, together with its statues, were socialised in August 2019 and reached legal status in January 2021, thus setting the foundation date of the SBDCh.

Future challenges of the development biology community in Chile

Developmental Biology is arriving at a new era in Chile. The developmental biology community comprises nearly forty principal investigators distributed in different universities of the country and covering a wide range of topics and model organisms (see list of all researchers in Fig. 8 and Table 3). Importantly, many of them are young and in the process of consolidating their scientific careers. Their drive and energy, combined with the experience of established researchers, and the diversity of topics and model organisms, are a strength of the community. But they also represent a challenge, as the needs of such a diverse group must be adequately articulated to take the discipline to the next level. The new SBDCh will play a vital role in this.

A future challenge of the developmental biology community is to become a relevant player in local and international settings. Scientifically, SBDCh will have to establish fruitful partnerships with scientific societies of Chile and abroad, especially the LASDB and ISDB, and make the best use of the broad capital of Chilean developmental biologists working in the US and Europe. The community of developmental biologists must also be proactive in disseminating the advances of the discipline and educating the population on the scientific and ethical consequences that developmental biology research has on human life. This last task is especially relevant. The recent advances in genetic manipulation and the *in vitro* generation of tissues and organs are just two examples where the developmental biology community has a word to say and a social role to play.

Acknowledgements

We are grateful to a long list of colleagues who kindly accepted our invitation for interviews and provided us with their experience, documents and photos that helped us constructing the history of developmental biology in Chile. For the first phase in the history of the discipline, we thank

[12]This change was not exclusive to Chile, but a reflection of transformations that scientific research experienced worldwide from the 2000s, with funding opportunities progressively re-focusing from basic research to more applied and biomedical science.

[13]RiBiD was conceived by Fernando Faunes and Carlos Oliva, and later directed by Carlos Oliva, Gonzalo Olivares, Natalia Sánchez and Esteban Contreras. The organisers of the RiBiD meetings are given in Table 1.

[14]The first informal conversations about the possibility of generating a society took place in the context of the third RiBiD meeting in January 2017. A few months later, a group of developmental biologists attending the 9th International Meeting of the LASDB in Medellin, Colombia, met to think about a plan and later recruited additional people to perform this task. The team included established principal investigators (Miguel Concha, Marcia Gaete, Sylvain Marcellini, Marcela Torrejón), young principal investigators (Ricardo Fuentes, Carlos Oliva, Gonzalo Olivares, Leonardo Valdivia), postdocs (Natalia Sánchez, Esteban Contreras) and students (Barbara Casas, Soraya Villaseca).

[15]The group was formed (in alphabetical order) by: Claudio Araya (principal investigator UACH), Miguel Concha (principal investigator UCH), Claudio Cortés (postdoc IBDM-CNRS-Aix Marseille University), Ricardo Fuentes (principal investigator UDEC), Marcia Gaete (principal investigator PUC), Sylvain Marcellini (principal investigator UDEC), Ignacio Medina (undergraduate student UCH), Gonzalo Olivares (principal investigator UCH), Marcela Torrejón (principal investigator UDEC), Cristián Undurraga (senior postdoc UCH), Leonardo Valdivia (principal investigator, UM) and Constanza Vásquez (Postdoc UCH).

(in alphabetical order) Jorge Allende, José Luis Arias, Jorge Babul, Eugenia Díaz, Soledad Fernández, David Lemus, Pablo Lois, Gloria Montenegro, María Angelica Montenegro, Ricardo Moreno, Nancy Olea, Mariana Rojas and Roxana Pey. Among them, we especially thank Roxana Pey for digging into memories, old documents and pictures that helped us constructing a phase in the history of developmental biology that was elusive due to the little written documentation available. From the interviews, we learnt about the love for the discipline that leaders such as Luis Izquierdo transmitted to students and colleagues, leaving an indelible mark that is present until today. We confess suffering not being able to interview them to discuss the topics of this article extensively. For the most recent phase in the history of the discipline, we thank (in alphabetical order) Miguel Allende, Juan Larraín, Sylvain Marcellini, Alfredo Molina, Gonzalo Olivares, Roberto Mayor, Marcela Torrejón and Kathleen Whitlock. They all provided complimentary views of the most recent historical aspects of the discipline in Chile. We also thank Adriana Ahumada and Nicolás Vásquez for helping in transcription of interviews and in the design of some figures, respectively. This work was supported by the ANID (Chile) projects Millennium Institute P09-015-F, Fondecyt 1190806, PIA/ACT192015 and Fondap 15150012.

References

ALLENDE, M.L., AMSTERDAM, A., BECKER, T., KAWAKAMI, K., GAIANO, N., HOPKINS, N. (1996). Insertional mutagenesis in zebrafish identifies two novel genes, pescadillo and dead eye, essential for embryonic development. *Genes Dev* 10: 3141-3155.

BARONDES, S.H., (2011). Gunther S. Stent. 1924-2008, Biographical Memoirs. National Academy of Sciences.

BARROS, C. (1980). Embriología, in: García-Huidobro, F., Montero, E., Pérez Sánchez, A. (Eds.), Cincuentenario Facultad de Medicina. Pontificia Universidad Católica de Chile. Pontificia Universidad Católica de Chile, Santiago, Chile, pp. 149-151.

BARROS, C., BEDFORD, J.M., FRANKLIN, L.E., AUSTIN, C.R. (1967). Membrane vesiculation as a feature of the mammalian acrosome reaction. *J Cell Biol* 34: C1-5.

BARROS, C., SCHATTEN, G. (1993). Prof Dr Luis Izquierdo (1928-1992): His contributions to Developmental Biology. *Biol. Res.* 26: 407-410.

BARROS, C., YANAGIMACHI, R. (1971). Induction of zona reaction in golden hamster eggs by cortical granule material. *Nature* 233: 268-269.

CANOVAS, J., BERNDT, F.A., SEPULVEDA, H., AGUILAR, R., VELOSO, F.A., MONTECINO, M., OLIVA, C., MAASS, J.C., SIERRALTA, J., KUKULJAN, M. (2015). The Specification of Cortical Subcerebral Projection Neurons Depends on the Direct Repression of TBR1 by CTIP1/BCL11a. *J Neurosci* 35: 7552-7564.

CERVANTES-DIAZ, F., CONTRERAS, P., MARCELLINI, S. (2017). Evolutionary origin of endochondral ossification: the transdifferentiation hypothesis. *Dev Genes Evol* 227: 121-127.

CMD (2019). CellMorphoDynamics Latin America, http://www.cellmorphodynamics.cl.

CONCHA, M.L., ADAMS, R.J. (1998). Oriented cell divisions and cellular morphogenesis in the zebrafish gastrula and neurula: a time-lapse analysis. *Development* 125: 983-994.

CONCHA, M.L., BIANCO, I.H., WILSON, S.W. (2012). Encoding asymmetry within neural circuits. *Nat Rev Neurosci* 13: 832-843.

CONCHA, M.L., BURDINE, R.D., RUSSELL, C., SCHIER, A.F., WILSON, S.W. (2000). A nodal signaling pathway regulates the laterality of neuroanatomical asymmetries in the zebrafish forebrain. *Neuron* 28: 399-409.

CORTES-CAMPOS, C., LETELIER, J., CERIANI, R., WHITLOCK, K.E. (2015). Zebrafish adult-derived hypothalamic neurospheres generate gonadotropin-releasing hormone (GnRH) neurons. *Biol Open* 4: 1077-1086.

DEVÉS, R., (1993). Homenaje al Dr. Luis Izquierdo Fernández. A cargo de la Sociedad de Biología Celular de Chile, VII Reunión Anual, Sociedad de Biologia de Chile. August 24-28., Valdivia, Chile.

EDWARDS, S.S., ZAVALA, G., PRIETO, C.P., ELLIOTT, M., MARTINEZ, S., EGANA, J.T., BONO, M.R., PALMA, V. (2014). Functional analysis reveals angiogenic potential of human mesenchymal stem cells from Wharton's jelly in dermal regeneration. *Angiogenesis* 17: 851-866.

ENAULT, S., MUNOZ, D.N., SILVA, W.T., BORDAY-BIRRAUX, V., BONADE, M., OULION, S., VENTEO, S., MARCELLINI, S., DEBIAIS-THIBAUD, M. (2015). Molecular footprinting of skeletal tissues in the catshark Scyliorhinus canicula and the clawed frog *Xenopus* tropicalis identifies conserved and derived features of vertebrate calcification. *Front Genet* 6: 283.

ERRÁZURIZ, J. (2018). Resistencia intelectual a la dictadura: el caso de la AUCAB. *Revista de Humanidades* 38 (Julio-Diciembre): 235-244.

FERNANDEZ, J., STENT, G.S. (1980). Embryonic development of the glossiphoniid leech Theromyzon rude: structure and development of the germinal bands. *Dev Biol* 78: 407-434.

FERNANDEZ, J.H., FERNANDEZ, M.S. (1974). Morphological evidence for an experimentally induced synaptic field. *Nature* 251: 428-430.

FUENTES, P., CANOVAS, J., BERNDT, F.A., NOCTOR, S.C., KUKULJAN, M. (2012). CoREST/LSD1 control the development of pyramidal cortical neurons. *Cereb Cortex* 22: 1431-1441.

GAETE, M., MUNOZ, R., SANCHEZ, N., TAMPE, R., MORENO, M., CONTRERAS, E.G., LEE-LIU, D., LARRAIN, J. (2012). Spinal cord regeneration in *Xenopus* tadpoles proceeds through activation of Sox2-positive cells. *Neural Dev* 7: 13.

GAIANO, N., AMSTERDAM, A., KAWAKAMI, K., ALLENDE, M., BECKER, T., HOPKINS, N. (1996). Insertional mutagenesis and rapid cloning of essential genes in zebrafish. *Nature* 383: 829-832.

GUERRA, M.M., HENZI, R., ORTLOFF, A., LICHTIN, N., VIO, K., JIMENEZ, A.J., DOMINGUEZ-PINOS, M.D., GONZALEZ, C., JARA, M.C., HINOSTROZA, F., RODRIGUEZ, S., JARA, M., ORTEGA, E., GUERRA, F., SIVAL, D.A., DEN DUNNEN, W.F., PEREZ-FIGARES, J.M., MCALLISTER, J.P., JOHANSON, C.E., RODRIGUEZ, E.M. (2015). Cell Junction Pathology of Neural Stem Cells Is Associated With Ventricular Zone Disruption, Hydrocephalus, and Abnormal Neurogenesis. *J Neuropathol Exp Neurol* 74: 653-671.

HERNANDEZ, P.P., OLIVARI, F.A., SARRAZIN, A.F., SANDOVAL, P.C., ALLENDE, M.L. (2007). Regeneration in zebrafish lateral line neuromasts: expression of the neural progenitor cell marker sox2 and proliferation-dependent and-independent mechanisms of hair cell renewal. *Dev Neurobiol* 67: 637-654.

IBAR, C., CATALDO, V.F., VASQUEZ-DOORMAN, C., OLGUIN, P., GLAVIC, A. (2013). *Drosophila* p53-related protein kinase is required for PI3K/TOR pathway-dependent growth. *Development* 140: 1282-1291.

IZQUIERDO, L. (1954). [Method of vital staining with toluidine blue; some results with rat eggs]. *C R Seances Soc Biol Fil* 148: 1504-1507.

IZQUIERDO, L. (1955). [Fixation of rat ova after vital staining with toluidine blue; technic and cytologic observations]. *Arch Biol (Liege)* 66: 403-438.

IZQUIERDO, L. (1983). Sobre la enseñanza de ciencias básicas de las escuelas de medicina chilenas. *Vida Médica* 34: 2 (Revista del Colegio Médico de Chile; Santiago, Chile).

IZQUIERDO, L. (1987). Sobre el futuro Gobierno Universitario, Realidad Universitaria *Revista del Centro de Estudios de la Realidad Contemporánea*. 1: 40-42. (Academia de Humanismo Cristiano. Santiago, Chile).

IZQUIERDO, L. (1991). The beginning of mammalian development. *Arch. Biol. Med. Exp.* 24: 215-228.

IZQUIERDO, L., VIAL, J.D. (1962). Electron microscope observations on the early development of the rat. *Zeitschrift für Zellforschung* 56: 157-179.

LENNON ZANINOVIC, M., (2012). La faceta más íntima de Juan Pablo Izquierdo, El Mercurio newspaper (Chile) 9 Septiembre, Santiago, Chile.

MARCELLINI, S., SIMPSON, P. (2006). Two or four bristles: functional evolution of an enhancer of scute in Drosophilidae. *PLoS Biol* 4: e386.

MENA, W., DIEGELMANN, S., WEGENER, C., EWER, J. (2016). Stereotyped responses of *Drosophila* peptidergic neuronal ensemble depend on downstream neuromodulators. *Elife* 5: e19686.

MENDOZA-TOPAZ, C., URRA, F., BARRIA, R., ALBORNOZ, V., UGALDE, D., THOMAS, U., GUNDELFINGER, E.D., DELGADO, R., KUKULJAN, M., SANXARIDIS, P.D., TSUNODA, S., CERIANI, M.F., BUDNIK, V., SIERRALTA, J. (2008). DLGS97/SAP97 is developmentally upregulated and is required for complex adult behaviors and synapse morphology and function. *J Neurosci* 28: 304-314.

MORENO, R., SANTOS, M.J. (2011). Editorial. A tribute to Professor Claudio Barros (1936-2008). *Biol. Res.* 44: 117.

MULNARD, J.G. (1992). The Brussels School of Embryology. *Int J Dev Biol* 36: 17-24.

MUNOZ, R., MORENO, M., OLIVA, C., ORBENES, C., LARRAIN, J. (2006). Syndecan-4 regulates non-canonical Wnt signalling and is essential for convergent

and extension movements in *Xenopus* embryos. *Nat Cell Biol* 8: 492-500.

MUÑOZ GALVEZ, V. (2015). La Facultad de Ciencias relatada por sus protagonistas, in: Chelech, F.Z. (Ed.), Anales de la Universidad de Chile. Universidad de Chile, Santiago, Chile, pp. 163-234.

OELGESCHLAGER, M., LARRAIN, J., GEISSERT, D., DE ROBERTIS, E.M. (2000). The evolutionarily conserved BMP-binding protein Twisted gastrulation promotes BMP signalling. *Nature* 405: 757-763.

OLIVA, C., SIERRALTA, J. (2010). Regulation of axonal development by the nuclear protein hindsight (pebbled) in the *Drosophila* visual system. *Dev Biol* 344: 911-921.

OTEIZA, P., KOPPEN, M., CONCHA, M.L., HEISENBERG, C.P. (2008). Origin and shaping of the laterality organ in zebrafish. *Development* 135: 2807-2813.

PALMA, V., LIM, D.A., DAHMANE, N., SANCHEZ, P., BRIONNE, T.C., HERZBERG, C.D., GITTON, Y., CARLETON, A., ALVAREZ-BUYLLA, A., RUIZ I ALTABA, A. (2005). Sonic hedgehog controls stem cell behavior in the postnatal and adult brain. *Development* 132: 335-344.

PEREDA, J., CROXATTO, H.B. (1978). Ultrastructure of a seven-cell human embryo. *Biol Reprod* 18: 481-489.

PEREDA, J., MOTTA, P.M. (1991). A unique fibrillar coat on the surface of migrating human primordial germ cells. *Arch Histol Cytol* 54: 419-425.

PEREZ, V., BERMEDO-GARCIA, F., ZELADA, D., COURT, F.A., PEREZ, M.A., FUENZALIDA, M., ABRIGO, J., CABELLO-VERRUGIO, C., MOYA-ALVARADO, G., TAPIA, J.C., VALENZUELA, V., HETZ, C., BRONFMAN, F.C., HENRIQUEZ, J.P. (2019). The p75(NTR) neurotrophin receptor is required to organize the mature neuromuscular synapse by regulating synaptic vesicle availability. *Acta Neuropathol Commun* 7: 147.

REIG, G., CERDA, M., SEPULVEDA, N., FLORES, D., CASTANEDA, V., TADA, M., HARTEL, S., CONCHA, M.L. (2017). Extra-embryonic tissue spreading directs early embryo morphogenesis in killifish. *Nat Commun* 8: 15431.

RIVAS, J., BUSTOS, J., ROJAS, M. (2014). Juan Eduardo Bustos-Obregón (1937-2014). *Int J Morphol* 32: 1509-1516.

SBCH (2019). Sociedad de Biología de Chile: 90 años de investigación y difusión científica, https://www.biologiachile.cl/sociedad-de-biologia-de-chile-90-anos-de-investigacion-y-difusion-cientifica .

STANIC, K., SALDIVIA, N., FORSTERA, B., TORREJON, M., MONTECINOS, H., CAPRILE, T. (2016). Expression Patterns of Extracellular Matrix Proteins during Posterior Commissure Development. *Front Neuroanat* 10: 89.

STENT, G.S. (1963). Molecular Biology of Bacterial Viruses. Freeman, San Francisco, US.

THE ROCKEFELLER FOUNDATION, 1954. Annual Report, 1954, New York, US.

THE ROCKEFELLER FOUNDATION, 1964. Annual Report for 1964, New York, US.

THE ROCKEFELLER FOUNDATION, 1968. President's five-year review & Annual Report 1968, New York, US.

THIEFFRY, D. (2001). Rationalizing early embryogenesis in the 1930s: Albert Dalcq on gradients and fields. *J Hist Biol* 34: 149-181.

TORO-TAPIA, G., VILLASECA, S., BEYER, A., ROYCROFT, A., MARCELLINI, S., MAYOR, R., TORREJON, M. (2018). The Ric-8A/Galpha13/FAK signalling cascade controls focal adhesion formation during neural crest cell migration in *Xenopus*. *Development* 145: dev164269.

TORREALBA RUIZ-TAGLE, C. (2013). Juan de Dios Vial Correa, Pioneros. El inicio de la biología experimental en Chile. Editorial Ciencia & Vida, Santiago, Chile, pp. 268-295.

TORRES-FUENTES, J.L., RIOS, M., MORENO, R.D. (2015). Involvement of a P2X7 Receptor in the Acrosome Reaction Induced by ATP in Rat Spermatozoa. *J Cell Physiol* 230: 3068-3075.

TORRES-PAZ, J., WHITLOCK, K.E. (2014). Olfactory sensory system develops from coordinated movements within the neural plate. *Dev Dyn* 243: 1619-1631.

URETA, T. (1978). La Sociedad de Biología de Chile: morfofisiología de una comunidad simbiótica. *Biol. Res.* 11: 41-43.

VARGAS, J.E., CHAQUI, B., DUARTE, I. (2005). Entre el crecimiento y la crisis, 1956-1967, Médicos de Ciencia y Conciencia. La Escuela de Medicina de la Pontificia Universidad Católica de Chile. Ediciones Universidad Católica de Chile, Samtiago, Chile, pp. 163-246.

VARGAS, L. (1980). Las ciencias biológicas en la Pontificia Universidad Católica de Chile, in: García-Huidobro, F., Montero, E., Pérez Sánchez, A. (Eds.), Cincuentenario Facultad de Medicina. Pontificia Universidad Católica de Chile. Pontificia Universidad Católica de Chile, Santiago, Chile, pp. 107-110.

VILLEGAS, R., MARTIN, S.M., O'DONNELL, K.C., CARRILLO, S.A., SAGASTI, A., ALLENDE, M.L. (2012). Dynamics of degeneration and regeneration in developing zebrafish peripheral axons reveals a requirement for extrinsic cell types. *Neural Dev* 7: 19.

WEISBLAT, D., THOMPSON, W. (2008). Gunther Stent. *Current Biology* 18: R585-587.

WHITLOCK, K.E. (2014). Zebrafish Invade Valparaiso: Third Meeting and Symposium of the Latin American Zebrafish Network. *Zebrafish*.

YUNES, R. (2009). Obituary. Claudio Barros, PhD (1936-2008). *Biocell* 33.

Further Related Reading, published previously in the *Int. J. Dev. Biol.*

Early bases of modern Embryology in Spain: Microscopical Anatomy and the introduction of Cell Theory and Histology in their scientific and social European context
Roberto Marco-Cuellar and Juan Aréchaga
Int. J. Dev. Biol. (2009) 53: 1123-1143
https://doi.org/10.1387/ijdb.093020rm

Contributions to Neuroembryology of Santiago Ramon y Cajal (1852-1934) and Jorge F. Tello (1880-1958)
Luis Puelles
Int. J. Dev. Biol. (2009) 53: 1145-1160
https://doi.org/10.1387/ijdb.082589lp

A glance at Spanish Embryology and Teratology during the XX Century through the academic life of Francisco Orts-Llorca (1905-1993)
Juan Aréchaga, Juan Jiménez-Collado and Domingo Ruano-Gil
Int. J. Dev. Biol. (2009) 53: 1165-1177
https://doi.org/10.1387/ijdb.072492ja

A perspective on the development of Genetics in Spain during the XX Century
Alfonso Martinez-Arias
Int. J. Dev. Biol. (2009) 53: 1179-1191
https://doi.org/10.1387/ijdb.082811am

José-Antonio Campos-Ortega (1940-2004) and his scientific work - a personal perspective
Elisabeth Knust and Rainer Hertel
Int. J. Dev. Biol. (2009) 53: 1193-1203
https://doi.org/10.1387/ijdb.072480ek

A history of Evo-Devo research in Spain
Jaume Baguñà
Int. J. Dev. Biol. (2009) 53: 1205-1217
https://doi.org/10.1387/ijdb.072427jb

A small great history of the sister Societies of Developmental Biology in Spain and Portugal
Isabel Palmeirim and Juan Aréchaga
Int. J. Dev. Biol. (2009) 53: 1261-1268
https://doi.org/10.1387/ijdb.082714i