Building momentum through Networks: Bioimaging across the Americas. A report on the Latin American Bioimaging (LABI) and Bioimaging North America (BINA) 2023 meeting.

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Abstract

During September 2023, the two largest bioimaging networks in the Americas, Latin America Bioimaging - LABI and Bioimaging North America - BINA came together during a one-week meeting in Mexico. The aims of the meeting were to discuss progress achieved over the past year, to foster networking and collaborative efforts among members of both communities, to bring together key members of the international imaging community to promote the exchange of experience and expertise, to engage with industry partners, and to establish future directions within each individual network, as well as common goals. This meeting report summarizes the discussions exchanged, the achievements shared, and the goals set during the LABIxBINA2023: Bioimaging Across the Americas meeting.

LABI and BINA are collaborative networks interested in addressing the needs of bioimaging scientists (including training, education, and accessibility to imaging) across the Latin American and Caribbean countries and North American countries, respectively.

Latin American Bioimaging (LABI)

LABI is formed upon 3 main pillars: **building capacities**, which involves supporting training and career development programs; **building community**, which includes organizing annual meetings and satellite events as well as developing and maintaining a website and social media communication channels; and **promoting global integration** to the international bioimaging community. LABI was created in 2020 with seven-partners (Argentina, Brazil, Chile, Colombia, Mexico, Peru, and Uruguay). Its kick-off meeting happened in 2022 during their first in-person meeting in Montevideo, Uruguay. Over the last year, the number of members has increased by 117%, from 137 to almost 300 in 2023. Members represent 23 countries, of which 13 are Latin American or Caribbean (**Figure 1**). Latin Americans worldwide are encouraged to join, as LABI aims to serve as a network to reverse the brain drain faced in the region and forge bridges between Latin Americans at 'home' and abroad.

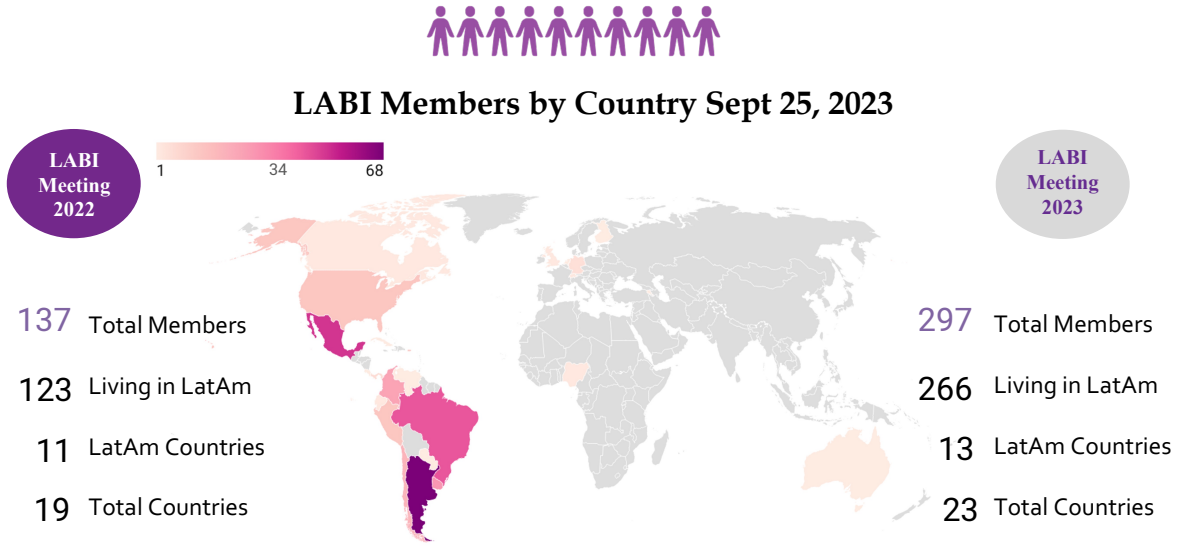


Figure 1. Infographic map of the evolution of the LABI community. The LABI community now comprises 297 members from 23 countries, 13 of which are in Latin America. Relative to 2022, membership saw a 2-fold increase, both in total numbers and in the number of Latin American countries where members reside. Map was created using Datawrapper.de.

As part of its structure, LABI has several working groups, including **Training and Education**, **Communication, Cooperation with partners, Outreach and Integration, and Corporate and Industry partners**. These working groups held round-table discussions during the LABIxBINA meeting, after which they gave updates of achievements and future directions. With the support of several partners, including the Chan Zuckerberg Initiative (CZI) and Invest in Open Infrastructure, LABI supports multiple travel awards for Latin Americans to strengthen capacity-building in the region, foster collaborations, and make the most of the regional expertise and infrastructure.

Bioimaging North America (BINA)

BINA is formed upon 4 main pillars: **Interaction**, **Education**, **Advocacy** and **Standardization**, with its core values being community, inclusion and excellence, the latter of which includes ensuring reproducible and quantitative methodology for microscopy. BINA was officially created in 2018 as a volunteer-based organization. Since 2021, and thanks to CZI, BINA has received funding that has been key for its efforts in community-building, dissemination, and training and education programs. Since its 2022 meeting, the number of BINA members has increased by over 50%, from 791 to 1,167 members at the time of the LABIxBINA2023 meeting. In addition to Canada, Mexico and the USA, members represent over 36 other countries including 5 from Latin America (Argentina, Brazil, Chile, Colombia and Uruguay) (**Figure 2**). BINA had six well-established working groups at the time of the meeting, namely Communications, Corporate Partners, Diversity, Equity & Inclusion, Image Informatics, Quality Control and Data Management, and Training and Education. Each working group presented detailed updates of their achievements over the past year, as well as future directions. Two emerging Working Groups, Builders and Early Career, were discussed with a co-chair from each new Working Group in attendance at the meeting and at this time these are now formal BINA Working Groups.

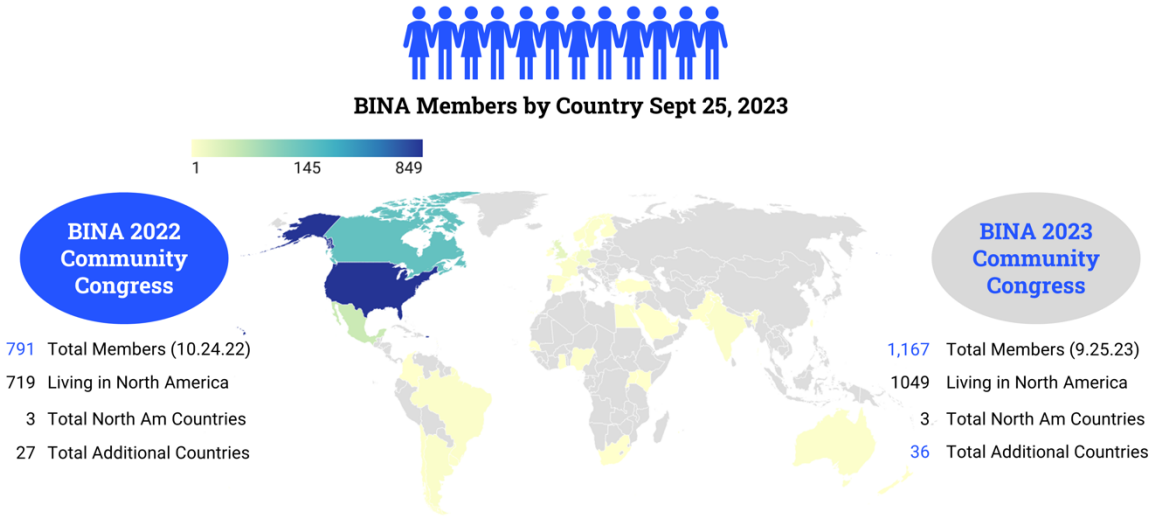


Figure 2. Infographic map of the evolution of the BINA community. The BINA community now comprises 1167 members from 36 countries, 3 of which are in North America. Relative to 2022, membership saw a 47% increase in total numbers and 33% increase in the number of countries where members reside. Map was created using Datawrapper.de.

The structure of the LABIxBINA 2023: Bioimaging Across the Americas meeting

The LABIxBINA 2023 meeting was aimed at establishing and strengthening strategic links between bioimaging professionals throughout the Americas and key global partners and stakeholders from Europe and Africa. This 5-day meeting provided opportunities for participants to closely interact with decision-makers from imaging core facilities across the Americas. The meeting was held in a hybrid format and attended by a total of 73 virtual and 87 in-person imaging scientists from the Americas, including Canada, USA, Mexico, Colombia, Peru, Argentina, Chile, Brazil, and Uruguay.

The LABI portion of the meeting took place between September 25th and September 26th, 2023, and was organized into sessions focused on two key topics:

- Expanding the core facility concept and discussing the role and aims of regional hubs in the Latin American Region to broaden and coordinate intra and inter-regional bioimaging opportunities. The session addressed the establishment, challenges, and sustainability strategies of bioimaging core facilities in Latin America, summarizing motivations, obstacles, and key lessons learned. Discussions included running initiatives to coordinate the integration of inter-regional research infrastructure (RI) programs.
- Pathways and opportunities for imaging scientist career development in Latin America: The session explored human resource challenges of bioimaging core facilities in Latin America, focusing on career pathways, recruitment, training issues, and the need for specialized development programs for attracting and retaining talent and fostering a diverse workforce in bioimaging core facilities.

The 10th Anniversary of the National Laboratory for Advanced Microscopy of Mexico (LNMA) was celebrated on September 27th, 2023, at the Biotechnology Institute of the National Autonomous University of Mexico. The event included a symposium and networking, offering attendees the chance to celebrate achievements, explore the role of Mexico in venom and antivenom research, or to participate in Exchange of Experience workshops to learn about managing the image-data life cycle for reproducible bioimaging experiments, with emphasis on Image Metadata, FAIR Data Management, and Integrated Imaging Pipelines.

The BINA Community Congress next took the stage from the late afternoon of September 27th to September 29th, 2023, to explore in detail:

- Educational and training opportunities: This segment focused on the different educational and training programs for imaging scientists across North America, aiming at equipping them with the knowledge and skills required to excel in their field.
- Technology development and Application: Aimed to share recent advances on technology development, their implementation, and practical applications.

The full meeting unfolded with the participation of invited guests from imaging networks including Euro-Bioimaging, BioimagingUK, German Bioimaging, and Africa BioImaging Consortium; corporate partners from AVR Optics, ZEISS, Bruker, Thermo Fisher Scientific, TissueGnostics, JEOL, Thorlabs, 3i and Omicron; and representatives of CZI, the latter of which has played a pivotal role in funding a wide range of projects including the consolidation and expansion of LABI and BINA.

The LABIxBINA 2023 meeting was opened with a message of encouragement from representatives of the Morelos Academy of Sciences, the Science and Technology Council of the State of Morelos, and the National Autonomous University of Mexico (UNAM, the largest public University of Mexico). They emphasized the importance of generating networks and synergies, and most importantly, the need to bring knowledge from the laboratory to the general population in the country, including rural and impoverished areas. They discussed **three main challenges present in Mexican science**.

- First, with fewer young people looking for careers in science, we need to re-think our roles as scientists, including how we are reaching out to the next generation.
- Second, the need for joined efforts between Mexican authorities and scientists, to ensure stable and adequate funding for science and technology. This contrasts with historical trends in Mexico, which have fallen well short of the politically agreed target of ensuring that 1% of the nation's gross domestic income goes towards research and technological development. At present, fast-tracked science legislation centralizes the decision-making process within the government, limiting the input of the scientific community.
- Third, it is crucial to ensure the transfer of knowledge across generations, which involves enhancing educational systems and making scientific knowledge accessible to society in a sustainable manner. This approach guarantees that opportunities for learning and innovation remain available to future generations.

Their closing message was that meetings such as LABIxBINA are key for us to share the different experiences of our regions, to ensure a better understanding of the challenges and the realities we are facing together. Equally, they emphasized that we must work together as scientific representatives, re-defining the role of our duties as scientists, to improve public perceptions of the importance of scientific endeavor, and improve access to scientific careers.

LABI

Expanding core facilities and regional hubs in Latin America

Bioimaging Core Facilities are centers whose function is to provide the necessary infrastructure, expertise, and critical bioimaging resources for many researchers. Bioimaging Core Facilities enable biomedical research through access to imaging technologies and expertise. At the forefront of Bioimaging Core Facilities is the expertise of Imaging Scientists, professionals who

are essential in understanding, operating, customizing, generating and implementing technologies, designing experiments, preparing specimens, gathering data, educating, training, and supporting researchers, analyzing and interpreting images, and drawing scientific conclusions. A vital aspect of developing core facilities has been the transfer of infrastructure from scattered individual laboratories through consolidation in centralized facilities, ensuring equitable access to state-of-the-art technologies and expertise by all research groups within institutes. The concept of Bioimaging Hubs in Latin America and the Caribbean arose from the collaboration between the Euro-Bioimaging ERIC (European Research Infrastructure Consortium), and specific centers in Latin America and the Caribbean that developed unique expertise and established advanced technologies at entry- or middle-level Research Infrastructures.

The main goal is that regional Hubs are able to support local or regional cores to develop projects to a level at which researchers can benefit from existing opportunities in high-end Research Infrastructure centers in the EU. Thus, extending this model and such services beyond individual institutions by expanding resource centralization to national, regional, and international scales should facilitate and coordinate access to any scientist in Latin America and the Caribbean. Like core facilities, bioimaging hubs are dedicated to balancing resource distribution and broadening access for a broad audience, encompassing the scientific, commercial, and public sectors. Bioimaging hubs play a crucial role in facilitating groundbreaking discoveries in biomedical research by focusing on strengthening the nexus between imaging expertise and resources. Their ultimate goal extends beyond merely facilitating equitable access: it also enables researchers worldwide to conduct studies that might not seem plausible to an individual research laboratory or institution due to limited access to high-end resources, knowledge, and research infrastructure. Hubs are essential in regions where access to resources greatly varies between countries, providing a foundation for scientific paradigm shifts. One crucial aspect to be highlighted is that there are already existing bioimaging centers in Latin America that can be considered regional Hubs, such as CENABIO in Brazil and UBA in Uruguay. Nevertheless, the challenge at present is how to coordinate, connect, and align their goals to take better advantage of the existing opportunities with bioimaging centers around the globe.

Pathways to Bioimaging Core Facility creation in Latin America

During this session, the various speakers highlighted key evolutionary steps and achievements of the facilities they lead, as well as noting the challenges that exist for the creation and maintenance of facilities in different Latin American countries.

Core facility creation in Mexico: LNMA and LabNalCit

Chris Wood and Gloria Soldevila spoke about the foundation and evolution of two reference facilities they each respectively lead in Mexico: the Laboratorio Nacional de Microscopía Avanzada (LNMA) and the Laboratorio Nacional de Citometría de Flujo (LabNalCit). LNMA not only harbors state-of-the-art microscopes including the latest platforms for super-resolution microscopy and multi-modal imaging, but has also been a key player in the democratization of microscopy. This was achieved through initiatives such as fostering the creation of Mexico Bioimaging, along with several outreach and dissemination initiatives deployed both at the national and international levels. As a reference center, LNMA serves hundreds of users form academia, industry, and general society. Likewise, outreach initiatives founded at LNMA have been deployed at a country level through an award-winning design program for 3D-printed microscopes (now progressing as a successful spin-off company). Public participation workshops are included within academic activities, such as the three-year Mexican Bioimaging Workshop program currently

underway at sites across the country. LabNalCit on the other hand, has latest generation flow cytometers, including analyzers and cell sorters, that serve as inter-institutional resources across the country supporting a wide range of projects relevant to the research landscape in Mexico. Areas of research of the LabNalCit include the study of infectious microorganisms, immune cell subpopulations, genome size and ploidy level in plants, mesenchymal stem cells, extracellular vesicles. Additionally, LabNalCit contributes to cancer research, and public health efforts, including responsiveness during the COVID-19 pandemic, and good manufacturing practices (GMP)-compatible regulatory T cell therapies for organ transplantation.

The Directors of LNMA and LabNalCit shared their views on factors that are key to the creation of core facilities: strategic and thorough planning; ensuring institutional support; and engaging the community. Key pillars to both facilities are supporting research and providing specialized services for research and clinical projects, as well as teaching and capacity building (through the organization of workshops, courses, and certifications accessible to scientists throughout the country). Shared challenges included high maintenance costs, exceptionalism among academic staff regarding access to resources and the role of facilities; and difficulties in navigating multi-funder bureaucracies. Despite these challenges, both core facilities have played a vital role in re-shaping the research landscape in Mexico, becoming established as national reference centers, and investing in human resources.

Advancing biomedical research in Argentina through access to state-of-the-art imaging technologies: CEMINCO and FIL

Gustavo Chiabrando and Andres Rossi spoke about the foundation and evolution of two core facilities and one National Microscopy System in Argentina, namely, the Centro de Micro y Nanoscopía de Córdoba (CEMINCO), Argentina, and the Fundación Instituto Leloir (FIL), which they respectively lead. CEMINCO functions as a central unit shared between Centro de Investigaciones en Química Biológica de Córdoba (CIQUIBIC – CONICET-UNC), Instituto Mercedes and Martín Ferreyra (IMMF-CONICET-UNC) and Centro de Investigaciones en Bioquímica Clínica e Inmunología (CIBICI-CONICET-UNC). CEMINCO has been central to the development of specialized microscopy platforms in Argentina including super-resolution, two-photon and confocal microscopy. The imaging core at FIL, was discussed as an example of the relevance of core facilities in crisis management, namely the COVID-19 pandemic, where volunteers worked together towards establishing testing and monitoring workflows as well as vaccine development and distribution. Both speakers identified key factors for the creation of a facility. Among them are identifying pressing needs among the researchers; securing motivated human resources; fostering curiosity; ensuring institutional support; and securing adequate funding to expedite research and technology development. In addition, factors vital for the long-term maintenance of facilities are standardization of autonomous user training, implementation of regular quality control, calibration and maintenance programs; and implementation and/or expansion of image analysis services. Conversely, key challenges faced in Argentina include the lack of recognition of the relevance and value of facilities, and the lack of sustained governmental support. Complementary to the discussion of both individual facilities was the presentation on the Argentine National System for Microscopy (Sistema Nacional de Microscopía (SNM)), the National Systems (Sistemas Nacionales) and the National Booking System (Sistema de Gestión de Turnos). The SNM is unique in its kind worldwide, in its efforts to ensure country-wide access and information on resource availability. Recently, Argentina joined as a signatory to the Global Bioimaging Memorandum of Understanding and was recognized for its unique and powerful initiative. Their program altogether, compiles a database of all available research infrastructures, not only microscopy, in the entire country, with a booking system available to everyone, regardless of location or area of expertise. These initiatives have catalyzed democratic access to microscopy

in the country, as well as minimizing equipment redundancy, ensuring the timely replacement and upgrade of equipment, and its equitable geographic distribution.

Bringing volumetric imaging to the region: Light-Sheet Imaging at Universidad Mayor (LiSIUM)

Representing Chile, Alenka Lovy discussed LiSIUM, the Light Sheet Bioimaging Hub at Universidad Mayor, Chile. LiSIUM is a CZI-funded endeavor to create a specialized light sheet microscopy hub in Latin America, which aids in disseminating expertise and capacity development in the region. LiSIUM has led the organization of multiple workshops, seminars, and conferences to promote the use of lightsheet microscopy, as well as to train researchers on how to build their own equipment. Points which have been vital for the creation and development of LiSIUM include training and dissemination programs, especially as light sheet microscopy is an emerging technology in the region; and fostering collaboration, to promote sharing techniques, technical expertise, equipment, and infrastructure. Equally important for LiSIUM has been the need to maintain excellent communication with vendors, liaise with institutions, and actively disseminate information to the community.

Altogether, all presenters addressing the creation and evolution of core facilities in Chile, Mexico, and Argentina reached similar conclusions regarding the value of core facilities (**Figure 3**).

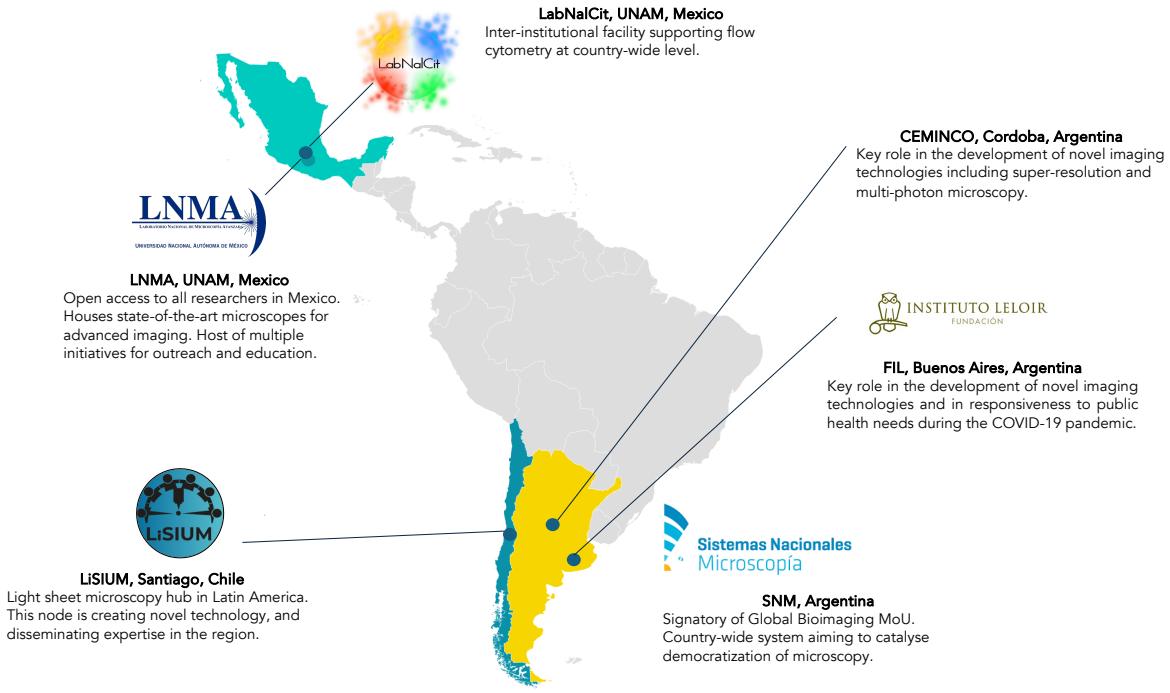


Figure 3. Infographic map of examples discussed during the LABIxBINA meeting on core facility creation in Latin America. Directors of LabNalCit (Mexico), LNMA (Mexico), CEMINCO (Argentina), Fundación Instituto Leloir (Argentina) and LiSIUM (Chile) spoke about the creation of these facilities, challenges, and future directions. Map created with Datawrapper.de.

Bioimaging Hub models from around the world, and the creation of Bioimaging Hubs in Latin America

Bioimaging Hubs are designed to facilitate access to microscopy at regional, country, continent, or worldwide levels. Such models are already operational in various regions of the world, and four international speakers were invited to the LABIxBINA meeting to share their experiences. They included Antje Kepler, representing Euro-Bioimaging and the European Research Infrastructure Consortium (ERIC); Teng-Leong Chew, representing the Advanced Imaging Center (AIC) at the HHMI Janelia Research Campus; Caron Jacobs, representing the African Bioimaging Consortium and the Africa Microscopy Initiative (AMI), and Vladimir Ghukasyan, representing the Chan Zuckerberg Initiative (CZI). These hubs share the aim of fostering collaborative work among researchers from different parts of the world; promoting open access, providing support and training; and emphasize a focus on international participation. Euro-Bioimaging consists of imaging facilities distributed across Europe. As part of their commitment to equitable science, they open various calls every year to support imaging for a range of biomedical research projects, and ensure that researchers worldwide can have access to the expertise and technology that the hubs offer, including funding for travel access costs. AIC Janelia, based in the USA, focuses on developing innovative technology, which can take a long time to be commercialized and made accessible to the scientific community. To break this barrier, AIC is distinguished for providing access to pre-commercial imaging technologies at no cost, through open calls for the selection of projects. Apart from its own program that supports the visit of national and foreign scientists to conduct research projects at AIC, with the support of CZI, they also have multiple courses and Bootcamps focusing on bioimaging at the Janelia campus and around the world. AIC has also played a central role in the development of networks such as the Africa Microscopy Initiative and is strong ally of LABI. Finally, the recently founded Africa Microscopy Initiative aims to tackle multiple barriers hindering access to microscopy in Africa, beyond research costs alone. Caron Jacobs highlighted that important features vital to the development of AMI have been: focusing on the regional and local needs and problems; generating multi-faceted programs that tackle complex barriers in the region; ensuring equipment access; developing training programs for capacity-building in the continent; developing infrastructure; ensuring investment; choosing a location for a continent-wide network such as AMI; and community-building and collaborations to ensure access to technology. Just as importantly, CZI has been a key player in funding microscopy worldwide and removing barriers to access. Recognizing that the development of new cutting-edge techniques faces multiple challenges including the long delay to commercialization and prohibitive costs, and that not all technologies are suitable for commercialization, CZI has developed strategies to ensure both access to technologies and specialized capacity building (including needs assessments, awareness, and training programs).

Highlighting the work done in Latin America, four speakers from Brazil, Uruguay and the Mercosur discussed the role of, and challenges and opportunities for, Bioimaging hubs in the region.

Establishing Cryo-EM in Latin America: CENABIO and CNPEM.

Kildare Miranda and Rodrigo Portugal discussed the work they have undertaken to build a Cryo-EM network in Brazil, specifically focusing on the National Center for Structural Biology and Bioimaging (CENABIO) in Rio de Janeiro, and the Brazilian Nanotechnology National Laboratory (LNNano/CNPEM) in São Paulo. The Cryo-EM network aims to interconnect facilities and research centers from the entire country, and currently includes national and regional hubs with cryo-EM and EM infrastructure. Together they highlighted several points for establishing a hub, including the importance of having a roadmap to infrastructure development; funding programs that support travel for capacity building and equitable distribution of expertise in the country; garnering community support and engagement; and customizing multidisciplinary

solutions to complex research problems. Additionally, both researchers emphasized the importance of sustained funding, the need for integration between facilities in a hub, and the importance of the creation of a critical mass of staff scientists to support cutting-edge technologies. They shared that beyond the acquisition of the relevant equipment, and the construction of suitable buildings for cryo-EM equipment, a challenge faced in Brazil is the uneven distribution of instruments in the country – something they hope the creation of hubs will address.

Paving the way: Uruguay's Advanced Bioimaging Unit (UBA)

Leonel Malacrida spoke about the creation and purpose of the Advanced Bioimaging Unit (UBA), a joint initiative between Institut Pasteur and Universidad de la República in Montevideo, Uruguay. The UBA was created to offer services and unrestricted access to cutting-edge optical microscopy to the entire Latin American region under four main pillars: **service**, **training and dissemination**, **technology-driven research**, and **biologically-driven projects**.

Leonel has identified several limitations in the Latin America, including funding constraints, the absence of a regional economic zone or commerce association (apart from Mercosur), and the lack of coordination and strategic planning in research infrastructure. These factors hinder the democratization of access to resources beyond the institute or country level, don't discourage duplication of efforts, hamper talent attraction, slow down technological development, and hinder partnerships with international centers. Despite these challenges, the transdisciplinary approach that UBA operates under has already brought about significant changes in the region. For instance, LABI operations are under the logistics of Institut Pasteur de Montevideo, and the UBA is responsible for its local affairs. Through the support received by CZI, the UBA has created a tailored training initiative to promote interest in advanced bioimaging tools. Since 2022, over 200 students have attended the Advanced Microscopy and Biophotonics annual workshops. More recently, the UBA has created a train-the-trainer (TtT) program to remove barriers to some advanced techniques developed at the institute. In the past two years, approximately fifteen core facilities from the region have benefited from the TTT program, and today, all these cores have fully adopted advanced tools such as hyperspectral imaging, phasor analysis, or label-retention expansion-microscopy. This kind of training has changed how LAC bioimaging cores approach advanced techniques, allowing them to answer new questions that could not be answered without these techniques.

Recently, Leonel introduced a new initiative at Institut Pasteur de Montevideo under the Hub concept. Together with Alejandro Buschiazzo (head of the Protein Crystallography Unit, PXF, Structural Biology core at Pasteur Montevideo), they are developing a Hub for Integrative Bioimaging that aims to provide imaging across scales from atoms or molecules to cells, tissue, and animals by adding Cryo-electron microscopy (Cryo-EM) and super-resolution (SR) microscopy to their existing technology and know-how. This Integrative Bioimaging Hub is cooperating with multiple partners from Europe and Latin America, to train their staff in new technologies (Cryo-EM and SR Microscopy) that the Integrative Bioimaging Hub will adopt. Supported by the 4th European Union -Latin America and the Caribbean (EU-LAC) Joint Call in Science Technology and Innovation (STI) 2022 for research infrastructure, the group proposes a bi-regional consortium to democratize access to entry and middle-level research infrastructures. This will also allow better integration and coordination with high-end level research infrastructures, it will help minimize duplicated efforts, reduce brain drain, and accelerate the development of cutting-edge technology and its applications in the region.

Finally, Leonel stressed the lack of regional agencies for coordination and funding of research infrastructures. He highlighted the need to start working more closely with organizations such as FOCEM (Fondo para la Convergencia Estructural del Mercosur) to offer some primary regional funds that can support coordinated research infrastructure in Latin American countries. He brought up the idea of establishing or supporting existing non-governmental funding agencies

to move forward the synergy between private and public funding to improve research infrastructure in the region as a critical tool to develop science and innovation, as an economic model for Latin America and the Caribbean.

Bioimaging hubs in Mercosur: CEBEM

Karina Alleva spoke about the role of Centro de Biología Estructural del Mercosur (CEBEM) as a network of nodes in the Mercosur (Mercosur is a union of countries in South America, which, similar to the European Union, enables travel, study, and work with total freedom for nationals of the various nations that integrate this union, namely Argentina, Brazil, Paraguay, Uruguay and Venezuela as state members, and Bolivia, Chile, Colombia, Ecuador, Guyana, Peru and Suriname as associated states). CEBEM's primary focus is the study of structural biology at nano- and atomic resolution. The network has been integrating centers across the subcontinent, with a current focus on enabling high-impact, multi-center research projects, regional and international collaboration, training human resources, and providing quality support for scientific visits. Key challenges have been adapting to fluctuating policies; engaging stakeholders and decision-makers; and securing sustainable funding. In the long-term, CEBEM aims to establish a regional agency with a shared agenda and initiatives that ensure equitable access.

Take-home messages from this section of the LABI meeting are summarized in **Figure 4.**

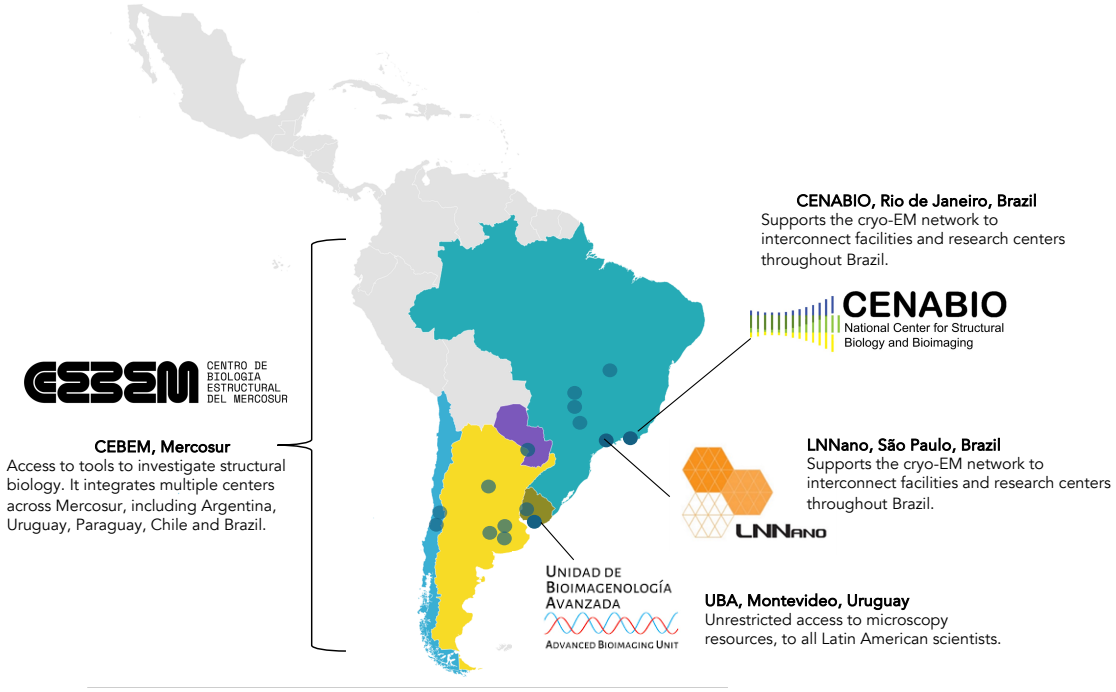


Figure 4. Infographic map of examples discussed during the LABIxBINA meeting on bioimaging-hub creation in Latin America. Directors and/or main leaders of CENABIO (Brazil), LNNano/CNPEM (Brazil), UBA (Uruguay) and CEBEM (Mercosur) spoke about the creation of these hubs, challenges, and future directions. Map was created using Datawrapper.de.

Diversifying Career Pathways in Latin America

The second major topic discussed during the LABI meeting was capacity building and human resources in the region. Of specific relevance were programs to train imaging experts, and career opportunities and expectations as an imaging scientist.

Professional Graduate Programs to form Imaging Scientists

Hernan Grecco, Director of the Department of Physics at Universidad de Buenos Aires, Argentina, began by highlighting that while the main components in a core facility are equipment, location, and operators, funding agencies rarely realize the relevance of investing in people. He emphasized the need not only to improve funding of training programs, but also the need for funders and the scientific community itself, to realize that training is a continuous process because knowledge and technology are in constant evolution.

Under this philosophy, several speakers presented teaching programs (undergraduate and graduate courses) that aim to train new generations of imaging professionals capable of addressing the ever-evolving needs of the scientific community. Hernan Grecco presented a program in Argentina called Carrera de Especialización en Microscopía; Silvana Allodi, from Universidade Federal do Rio de Janeiro (UFRJ), Brazil spoke about the graduate program in Technologies of Bioimaging and Biostructure hosted at UFRJ; and Luis F. Jiménez-García discussed the success story of the Specialty in Electron Microscopy for Biological Sciences Program, which since its foundation in 1987 has trained a vast number of EM specialists in Mexico, with important effects on the national academic research and technological capacities. Finally, Laura Daza spoke about the capacities of the Center for Research and Formation in AI (CinfonIA) in Colombia, the first of its type in Latin America, which include expertise in 3D Vision, image generation, segmentation and grouping, drug discovery, smart pooling, robotic assisted surgery, and social robotics, among others. CinfonIA, together with DeepMind, offers different types of funding to promote the creation of an inclusive AI community in the region. Among CinfonIA-led initiatives is a new Master's Program in AI, entirely taught virtually through the Coursera platform and fully taught in Spanish (thus eliminating the language barrier that often hinders inclusion in the region). Key points of this section of the LABI meeting are summarized in **Figure 5.**

Figure 5. Infographic map of examples discussed during the LABIxBINA meeting on professional postgraduate programs focused on Bioimaging in Latin America. Representatives of UNAM (Mexico), UFRJ (Brazil), UBA (Argentina), and CinfonIA (Colombia), spoke about important postgraduate courses held in their institutes, focusing on training bioimaging scientists. Map was created using Datawrapper.de.

Mobility between academic and commercial sectors in Latin America

Vital to diversifying career paths in bioimaging is awareness of the possibilities that exist beyond academia. During the LABIxBINA meeting, four scientists whose career paths involved major moves between environments gave their insights on what these changes entail. Natalia de Val, Senior Sales Development Scientist at Thermo Fisher Scientific, emphasized that core facilities are strategically placed to facilitate movement between academic and commercial sectors, and are well suited to promote collaborations with industry partners. Her main suggestions for researchers when transferring from academia to industry were to take calculated risks, to challenge oneself, to find the best timing to do the transition, and to network. Bruno Vale, Head of ZEISS Brazil, emphasized that communication between both sectors should improve, to enable a swift matching process between the talent pool and open positions. Vanessa de Sa from the Business Development Division and R&D Support of TissueGnostics Brazil emphasized the importance of establishing collaborations and familiarizing oneself with corporate jobs and businesses in the industry sector, early on in one's academic career. Complementary to these take-home messages, Vilma Jimenez Sabinina, Director CMC Analytical Strategy at Bayer, pointed out that the development of imaging-based methods that are key to biotech is an important bridge between the academic and industry spheres.

Creating and supporting career pathways for facility staff: messages from international guests

International speakers included Claire Brown, Peter O'Toole, Philip Hockberger and Beth Cimini. Together they explored the importance of 4 main topics: formal training programs; official career paths and recognition; management and leadership programs targeted to core facilities; and the development of interdisciplinary areas such as image analysis.

Training opportunities and top challenges for career development

Claire Brown and Peter O'Toole explored the role of networks such as Global Bioimaging and Bioimaging United Kingdom (UK) in the development of training programs and in facilitating access to expertise. They shared the recent international recommendation including a survey of the needs and expectations of the community regarding Career Development for Imaging Core Facility Staff. Additionally, Peter O'Toole highlighted the importance of the Technician Commitment in the UK (many imaging scientists being included in this important category of technicians), which focuses on aspects vital to core facility scientists: visibility, recognition, career development, and sustainability. Both speakers recognized top challenges faced by scientists at imaging facilities: poor recognition of the value of the work of imaging scientists; a divide between academic and core facility staff; the complexity of recruitment and retention; lack of sustainable funding mechanisms; and the need for better dissemination of success stories from around the globe (i.e. role models).

On a different note, Philip Hockberger explored the relevance of two core-specific job families: core technicians and core scientists, each with different skill sets and career potential. Moreover, he spoke about the Leadership and Management in Core Facilities Kellogg Course at Northwestern University, a hands-on program that explores topics including business management and leadership in an academic setting. Finally, Beth Cimini, whose leadership has been key to the development and evolution of CellProfiler open source image analysis software, shared her experience and take-home messages to scientists pursuing bioimage analysis as a career. She emphasized that different skills are required to manage data, compared to those used in the biomedical sciences. Yet, barriers impeding biologists from fully engaging in computer science-based disciplines include lack of time, lack of training, lack of experience and lack of confidence. Beth recognized that more data analysts are required, and that this is not just an expertise issue, but an equality issue. Through her leadership of CellProfiler and a formal training program, she hopes to facilitate the transition of biologists into the world of computer science; to convince the scientific community of the importance of image analysis (and image analysts); and to convince funding agencies about the need for training resources and sustainability of this discipline and of training resources.

Conclusion of LABI meeting

Two plenary talks during the LABI meeting were given by Dorit Hanein, who discussed major achievements and state-of-the-art techniques for cryogenic correlative light and transmission electron microscopies (cryo-CLEM), cryogenic transmission electron microscopy (cryo-EM) and *in situ* cryogenic cellular tomography (cryo-ET) – disciplines of microscopy currently gaining momentum in Latin America - and by Peter O'Toole, who discussed opportunities, challenges and future perspectives of career paths in core facilities. Takeaway messages delivered by Andres Olivera, LABI Manager, were the need to address strategies for accelerating the development of and access to innovative technologies in Latin America; the need to develop a common approach for funding; the role of LABI in promoting the dissemination of the regional hub concept and its development and expansion in the region; and the need to standardize and coordinate training pathways. The LABI meeting concluded with the announcement of the official foundation of Mexico Bioimaging, a network that will focus on

fostering collaborations and outreach programs throughout the country. Moreover, he announced the location of the 2024 LABI meeting, which will take place in Rio de Janeiro, Brazil.

A visit to the Institute of Biotechnology (UNAM) in Cuernavaca, provided an opportunity to bridge the LABI and BINA programs and celebrate the 10th Anniversary of the facility. There was an opportunity to hear from Prof. Alejandro Alagón, who leads the Antibody Biotechnology and Toxinology Group specializing in animal venoms and antivenoms for which Mexican research has maintained worldwide recognition for decades. Additionally there were opportunities for Pop-Up Exchange of Experiences: a visit to the LNMA facility, where attendees were able to interact with imaging experts, see the imaging infrastructure and capacities available at this important center and the first of two exchanges co-hosted by Beth Cimini and Caterina Strambio de Castillia entitled "Managing the image-data life cycle for the real world: connecting the dots from sample preparation, to image acquisition, analysis and publications". Attendees of this optional trip to Cuernavaca returned to the Hacienda Vista Hermosa to kick off the BINA meeting which was designed to dovetail with the LABI program, focusing first on the importance of training and education for bioimaging scientists and closing with technology development and its implementation and application.

BINA

The BINA meeting began with an inspiring homage, led by Claire Brown, to Michael W. Davidson's career as a highly versatile and multi-talented scientist, and an inspiration to much of the work that BINA does. He was a researcher, photographer, mentor, entrepreneur, storyteller, and a highly productive scientific author and microscopist with over 600 journal and magazine covers. With his artistic and graphical design skills, he generated a collection of cocktail ties and scarves, he imaged computer chips and developed websites for multiple microscopy companies including ZEISS, Olympus and Nikon. As a mentor, he trained over 500 young scientists across multiple areas, including website development, and graphic design. As a scientist, he developed a plethora of fluorescently-tagged proteins, and donated the largest collection of its kind to Addgene, as a major contribution to science. As part of his work with corporate partners, he collected camera quantum efficiency curves, characterized filter cubes, and consulted on microscopy hardware and software. He went above and beyond with his creative skills, including becoming an entrepreneur to inspire textile design based on microscopy images.

In this spirit, the BINA sessions highlighted the values of the versatility of microscopy as a career. They focused on 3 main topics: training and capacity-building (including technology transfer, imaging informatics, core facility leadership and management, and data management); how to measure impact; and the relevance of technology development, highlighting our role as creators that enable us to break different barriers, including those preventing equal access to technology and knowledge. Below we summarize the main discussions on each topic.

Training and Education Opportunities in North America

The session focused on training and education opportunities in four different areas: technology, image informatics, data management, and core facility management, and highlighted the different approaches being taken to meet each community's unique needs and opportunities, all converging on ensuring high quality bioimaging (**Figure 6**).

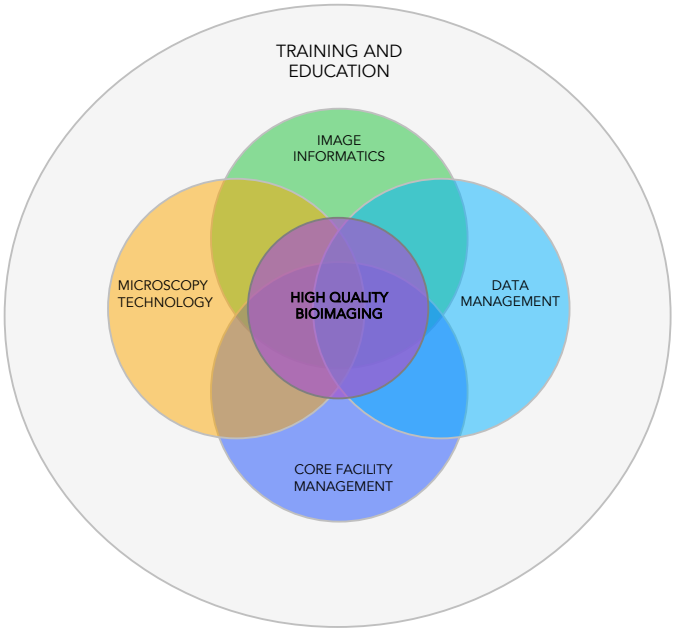


Figure 6. Venn diagram highlights the range of topics discussed in the context of BINA training and education. Topics discussed during the meeting included the importance of training in image informatics, microscopy technology, data management, and core facility management, all of which are key to ensure high quality bioimaging.

Training and Education: Microscopy Technology

Training courses in Canada

Representing Canada, Philip Kesner from McGill University introduced the Montreal Light Microscopy Course (MLMC) which was designed in the format of 'Train-the-Trainers' for the July 2023 edition, aimed at imaging scientists who intend to run their own courses on fundamental and advanced microscopy techniques. In addition to its main aim of providing a strong basis for event organization, the MLMC course promotes networking and collaborations between trainers in different countries, and aims to build groups and teaching materials together going forward. Many of the attendees and instructors are members of other interconnected networks, and meetings of such networks (e.g. BINA and LABI) have played an important role in disseminating information about MLMC. The program included an outreach event in the form of a kids' summer camp visit, bringing together many children across multiple age groups. This outreach activity was inspired by similar efforts being employed during Mexico BioImaging Workshops that were shared with the BINA audience at their 2022 Congress at Woods Hole. Key lessons learned include: knowing the target audience; organizing the course into modular sections that can be customized; tuning to the length of time; and reaching a balance between theory and practice. Main challenges identified include: a balance between senior and junior microscopists, and issues for some participants to obtain travel visas in time, which is a common barrier for many international meetings. Future plans for MLMC include: organizing group meetings with former participants to stay connected and collaborate; increasing communication and dissemination by writing articles regarding the course; planning virtual meetings for those participants who cannot obtain visas; ensuring ongoing access to resources; and designing the course with instructors from different facilities. Canada BioImaging, BINA, LABI, GBI and CZI were acknowledged for their input and support in making this meeting possible.

Training courses in the USA

Representing the USA, Alison North began by discussing various existing microscopy-specific courses, their benefits and philosophy. Among them were the MBL-led Optical Microscopy and Imaging in the Biomedical Sciences (OMIBS), Analytical and Quantitative Light Microscopy, and the Deep Learning for Microscopy and Image Analysis courses in Woods Hole, USA; the MDIBL Quantitative Fluorescence Microscopy course in Maine, USA; the Advanced Imaging Methods Workshop at the Cancer Research Laboratory at UC Berkeley, USA; and the Cold Spring Harbor Laboratory course on Quantitative Imaging: from Acquisition to Analysis. Many of these are included in BINA's Professional Development Program, enabling BINA members to apply for registration support to attend. Different stimulating questions were raised, regarding training courses in North America, for instance: why are these courses valuable? How are the participants selected when there are large numbers of applicants? What is the impact of existing courses in the larger scientific community in North America and elsewhere? How can BINA act as an amplifier of expertise in the region? And what defines a successful course? In summary, successful courses are characterized by versatile and complementary skills among the course directors and managers; an efficient, friendly and hard-working team of facilitators; an inspiring team of academic and commercial faculty with a clear love for teaching; and inspired and focused applicants that can make the most of the course and can amplify its benefits in their own institutions and beyond. Importantly, the success of many courses depends on corporate partners, funders and vendors. Lastly, Alison encouraged the organization of courses as a way for researchers to work towards a common goal in serving the scientific community, establishing networks with other partners and collaborators, and training the next generation of microscopy experts.

Training courses in Mexico

Representing Mexico was Mexico Bioimaging Director, Diego Delgado, who highlighted the efforts, successes, and progress of Mexican Bioimaging Workshops, now under the umbrella of the newly founded Mexico Bioimaging. He highlighted the role of Mexican Bioimaging Workshops in multi-pronged strategies for capacity-building in the country by creating collaborative alliances between existing core facilities. Mexico Bioimaging also aims to raise awareness about and facilitate the implementation of advanced microscopy techniques, both in scientific communities and the general population. With the support of CZI funding, Mexico Bioimaging has planned to organize 12 workshops on both fundamentals and advanced microscopy topics. In addition, they carry out outreach activities at public and private schools, science museums, and public parks. In the form of monitoring the effect of the various programs, Mexico Bioimaging surveys the general perception of microscopy after the workshops and outreach activities, focusing on intention, training, expectations and community-building.

Three very different approaches to technology training were shared, each with their own challenges and successes, providing the audience with an opportunity to evaluate those and alternative or additional approaches to consider in serving their community's training needs.

Figure 7 summarizes the courses discussed in this session.

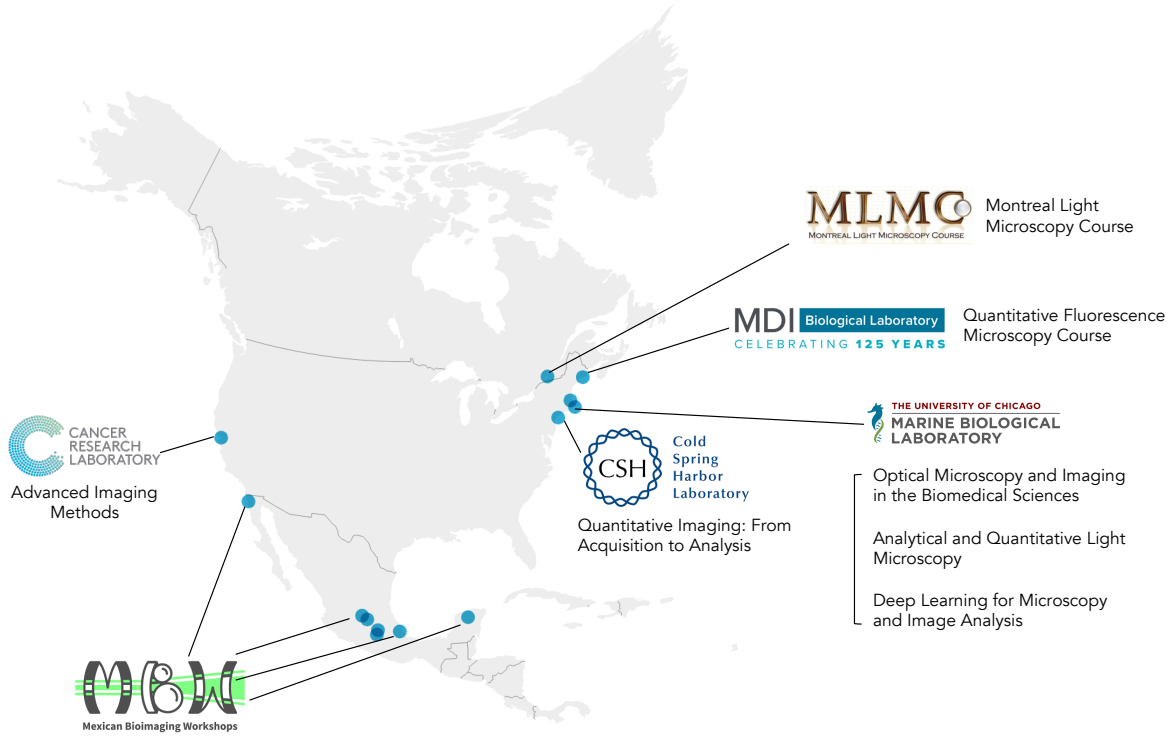


Figure 7. Infographic map showing the location of training opportunities discussed during the LABIxBINA meeting. Courses included those held at institutions in Montreal (Canada); in Woods Hole, New York, Bar Habor, and Berkeley (USA) and various locations in Mexico including Mexico City, Guerrero, Ensenada, Morelos, Yucatan, and Queretaro, organized by the Mexico Bioimaging Workshops. Map was created using Datawrapper.de.

Training and Education: Image Informatics

The image informatics session focused on initiatives from Canada, USA and Mexico, some of which have been developed and/or further expanded with the support of CZI. They include the projects 'Advancing Bioimaging Core Services with Artificial Intelligence' led by Paul Hernandez in Mexico, 'Bioimage analysis efforts in the USA and beyond' led by Beth Cimini in the USA, and 'Canadian resources and the AIMM user group' led by Judith Lacoste in Canada. Key messages are summarized in **Figure 8.**

Building on her presentation during the LABI program, Beth Cimini, leader of the CellProfiler open-source image analysis software project began this session by highlighting the fact that microscopy's history is mostly qualitative, with 60-80% of high-content imaging-based studies using only 1-2 cellular features. This is despite the fact that images contain extensive and important information in the form of features that can be quantified to give better insights into biological processes. While programming plays a major role in the big data revolution, many scientists involved in data acquisition are not always comfortable with, or at the vanguard of, computational programming. Specific challenges faced in data analysis education programs include the time commitment required to acquire a completely novel skillset associated with image analysis; the need for trained personnel capable of generating training programs; staff expertise to aid in the process of image analysis; and funding. Successful initiatives include the creation of bioimaging data analysis clusters, and building communities through networks including BINA, Network of European BioImage Analysts (NEUBIAS), Global BioImage Analysts' Society (GloBIAS), LABI,

and Royal Microscopical Society (RMS), among others. These bioimaging communities are succeeding in removing barriers to data analysis expertise worldwide through the development of educational webinars, repositories of training material, and in-person Pop-Up Exchange of Experience (EoE). Highlighted initiatives and/or events include Halfway to I2K, I2K, AI4Life, NEUBIAS, and forums such as image.sc, all of which are open to the scientific community and beyond. In addition, the image analysis community has generated important resources such as guidelines for bioimage analysis, to aid better reporting of imaging and image analysis in published articles. Beth concluded by identifying an important challenge that still remains: conveying the importance of image analysis to scientists, and making the scientific community conscious about the things they currently don't know about this topic, but which could benefit the quality of biological research. On a similar note, Paul Hernandez highlighted the progress made in the project 'Advancing Bioimaging Core Services with Artificial Intelligence', which he leads in Mexico. The aim of this CZI-funded initiative is to enhance tool creation focused on artificial intelligence use for image analysis; the creation of online courses and tutorials for wider dissemination; the creation of in-person workshops in English and Spanish; and the development of custom AI workflows tailored for biologists. Overall, this project aims to encourage biologists to explore AI tools and engage with image analysts for tailored solutions. This project has currently resulted in the generation of a wide range of courses, virtual meetings focused on image analysis fundamentals, and artificial intelligence workshops. In addition to formal courses, other forms of engagement integrated in this project are collaborations and the generation of user-friendly interfaces available on GitHub. Finally, Judith Lacoste, representing the Canadian resources/Automated Image Management and Metadata Annotation (AIMM) user group, focused on the importance of automation, open-access, reproducibility and findability of image analysis resources. She began by highlighting Quality Assessment and Reproducibility for Instruments & Images in Light Microscopy (QUAREP-LiMi), and the importance of FAIR (Findable, Accessible, Interoperable, and Reusable) standards for reproducible image data. Equally important is national support for digital research, which in Canada includes data centers around the country, connected by high-speed infinity band connections. The mission of the Digital Research Alliance of Canada (DRAC) is to provide support for advanced research computing, data management, and software development. Judith emphasized that in Canada there is significant support of databases such as Open Microscopy Environment (OMERO), and FAIR-science dynamics, exchange and sharing. Altogether, virtual environments can be key for big data, by bringing together people with different levels of expertise, fostering communication between them and users, and facilitating the provision of feedback in a non-technical way to facilitate information-sharing.

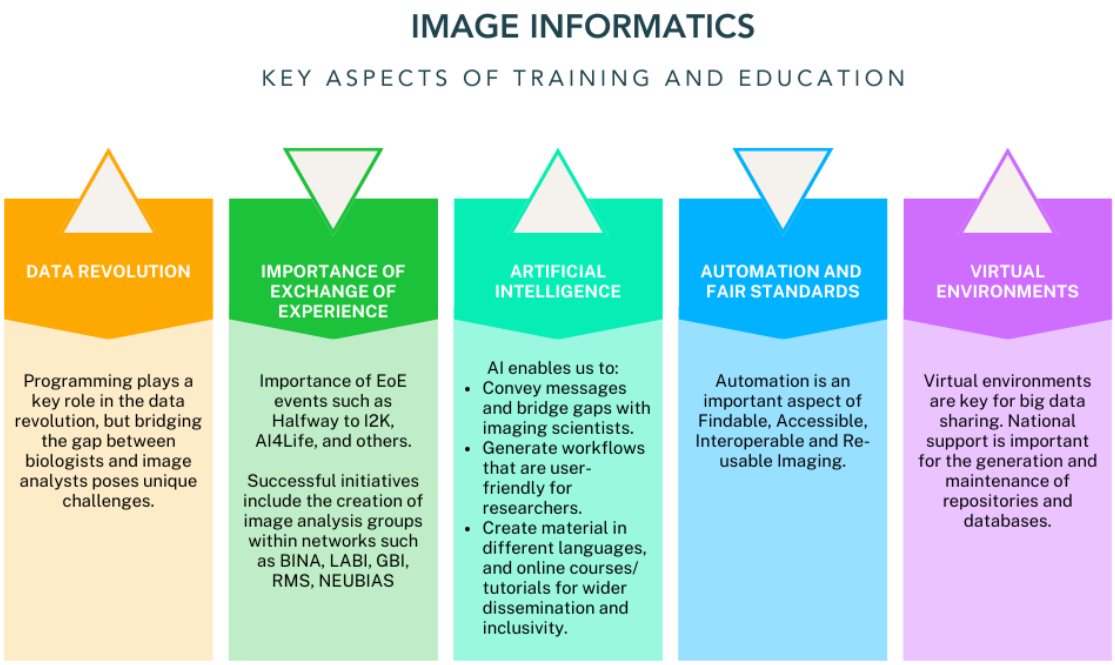


Figure 8. Summary of topics discussed relative to training and education in image informatics. This included a discussion on the role of programming in the data revolution, the importance of training, the relevance of AI in Microscopy, the importance of automation and FAIR standards, and the relevance of virtual environments and the maintenance of repositories and databases. Image created with Canva.

Training and Education: Core Facility Management

The core facility management session focused on the importance of core facility and business management training for imaging scientists. It included talks by Phil Hockberger, representing the Waymaker Group and the Kellogg's leadership course; Adan Guerrero from LNMA in Mexico, focusing on the GBI core facility management workshop held in person in Mexico earlier in the year; and Kate Luby-Phelps, who spoke about the Virtual Core Management training opportunities organized by BINA's Training and Education Working Group.

The session began with Phil Hockberger asking the question 'Why does a core director need training?' (**Figure 9**). The Core Director is an entrepreneur operating a small business with non-profit purposes, whose key responsibilities include leveraging their own and their staff's expertise to advance the research of their users; providing cost-efficient delivery of services; being part of collaborations and linkage; managing support for fee-for-service models; and facilitating applications of advanced technologies. Business training is therefore pivotal for a core director to advance research and research priorities; maximizing results; determining the scale of investment, demonstrating institutional impact, and ensuring sustainability of the facility. Opportunities for leadership training include ABRF online workshops and webinars; the German Bioimaging (GerBI-GMB) facility leadership and management course facilitated by hfp-consulting; Global Bioimaging online courses, and the Kellogg Leadership and Management in Core Facilities program organized at Northwestern University in Chicago. As an example of a syllabus, the latter includes modules such as strengthening organizational leadership; understanding marketing tools and team leadership; understanding marketing and pricing management; and strengthening team, leadership and management. An added advantage of these in person, multi-day courses is the opportunity to network and interact as a group and share experiences.

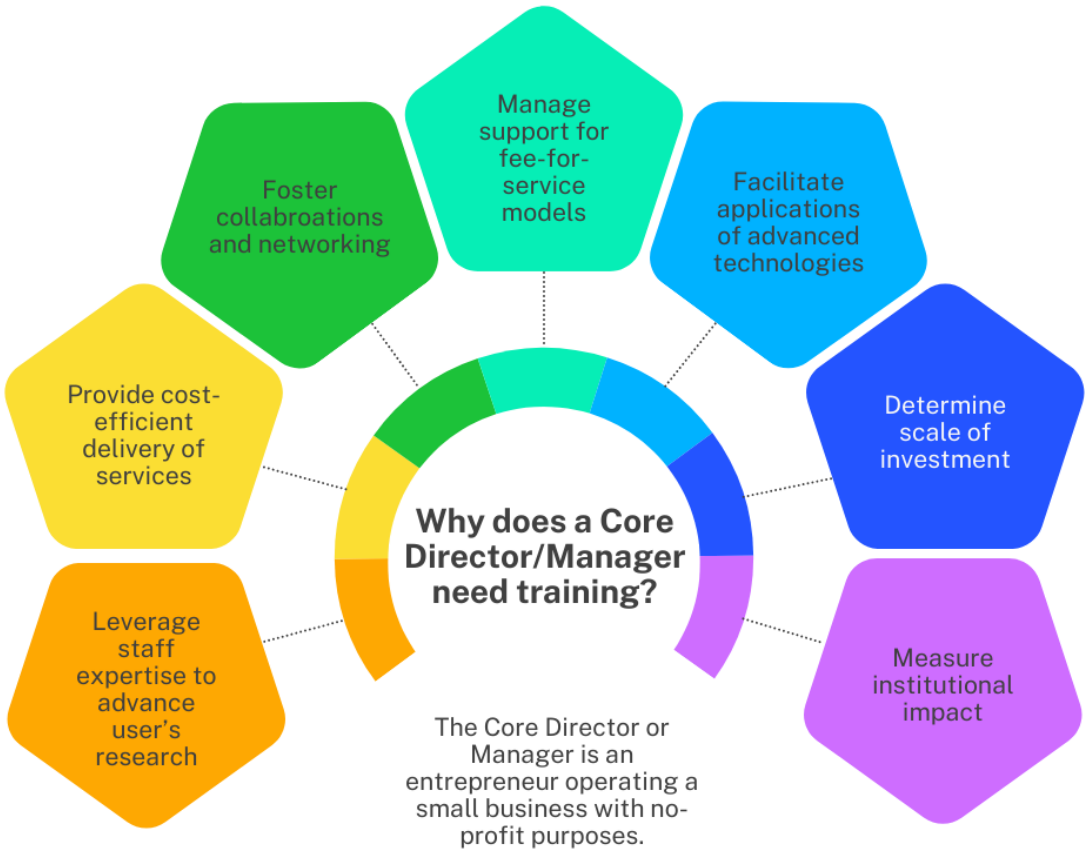


Figure 9. Summary of discussion on the importance of training for a Core Director or Manager. The discussion was centered around the versatile role of Core Directors, and the need for training in different areas including business management, leadership, marketing, and finances. Image created with Canva.

Within this context, GBI's training initiatives are divided into 3 areas: training for imaging core facility staff, international job shadowing program, and the GBI online training platform. Adan Guerrero focused on the main topics and learning outcomes of the in person GBI-LNMA course held in Cuernavaca earlier that year, which included measuring impact of imaging facilities; setting up and managing an imaging facility; user training and career development in core facilities; and image data management and data reuse through the use of image repositories. Learning outcomes included discussions about, and experience in, delegation and the importance of collaboration; avoiding micromanagement; fostering trust; prioritizing long-term sustainability as opposed to immediate perfection; and the importance of securing liquid funding well in advance, in order to avoid stifling of momentum due to lengthy administrative processes. Adan recognized the importance of teamwork and team support during the organization of these events, and he emphasized that without collaboration and funding support, the scientific relevance can be blurred due to excessive bureaucracies. Adan concluded by stating the importance of moving the trainers close to the people who need to be trained in this particular model. Complementary to both initiatives, Kate Luby-Phelps focused on the importance of offering virtual courses on leadership and management training. The main goals of virtual courses are to remove barriers by increasing affordability, time efficiency, and avoiding the need for expensive travel costs. Through BINA-led efforts, in 2022 a 4 week virtual course offered by hfp-consulting was selected. Conversely, in 2023, BINA facilitated independent, ad hoc virtual sessions led by Soft Skills Inc. Soft Skills Inc is a Canada-based firm, offering a modular format which takes place as 3-hour sessions on a monthly basis, increasing accessibility in terms of both cost, and time commitment. Importantly, a survey

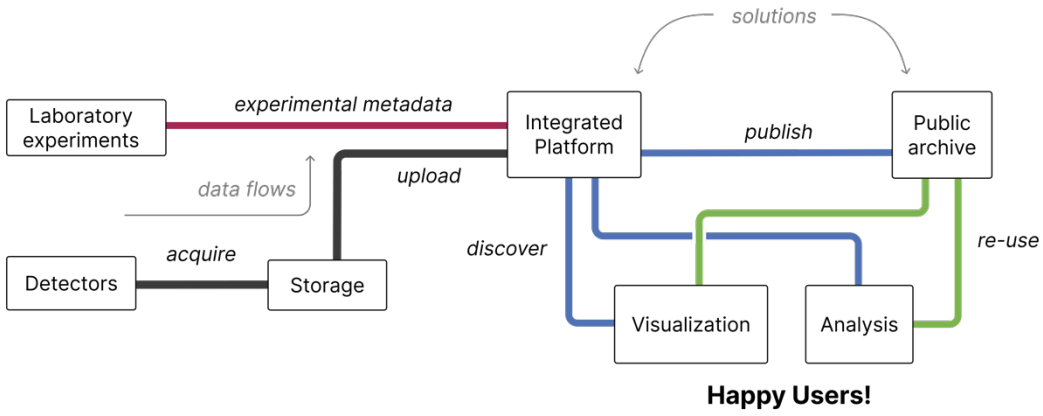
asking imaging scientists why they did not attend previous workshops showed that the main reasons included courses being too expensive, lack of time, topics of interest not being covered, and lack of interest in leadership training. Topics that were identified as important were both generic soft skills (i.e. leadership, communication, and supervision), and core-specific skills (such as proposal writing, workflow generation, defining service costs, preparing budgets, core management, and training users). The survey results will shape the direction of virtual courses BINA offers in the future.

This session once again emphasized the different approaches being taken to address each communities needs and provided an opportunity to share and learn from each other's experiences in organizing and hosting such training events. The MicroscopyDB project was mentioned as a resource for networks to share on-line training resources with their communities and have their community members contribute their own training resources to this centralized database.

Training and Education: Managing and Sharing Data

The 'Managing and sharing data' session focused on the importance of automated, open, reproducible and FAIR science, through the appropriate management and sharing of imaging data. The session was elegantly introduced by Judith Lacoste using the analogy of a car to help make the complexity of image data management more accessible. Presentations in this session were led by Josh Moore, focused on the car's systems and what's under the hood, Caterina Strambio-de-Castilla, focused on the car's dashboard or interface with the systems, and Caroline Miller, focused on the driver's role in the different aspects of image data and metadata.
Josh Moore introduced "BioImage Town", and noted that one of the reasons that research data management (RDM) is complex is due to the large quantity and variety of data being generated. OME-Files, Bio-Formats and OMERO aim to provide solutions and standardization to data management problems. Next-generation formats are multi-resolution data which do not require conversion between formats, thus reducing wasted storage when submitting and downloading images. Moreover, next-generation formats come closer to enabling upload and sharing of data through websites, wiki-sites, and forums, overcoming the need for databases. Moving forward, it will be vital to improve communication and increase engagement to better handle core-facilities' and researchers' needs (**Figure 10**).

A



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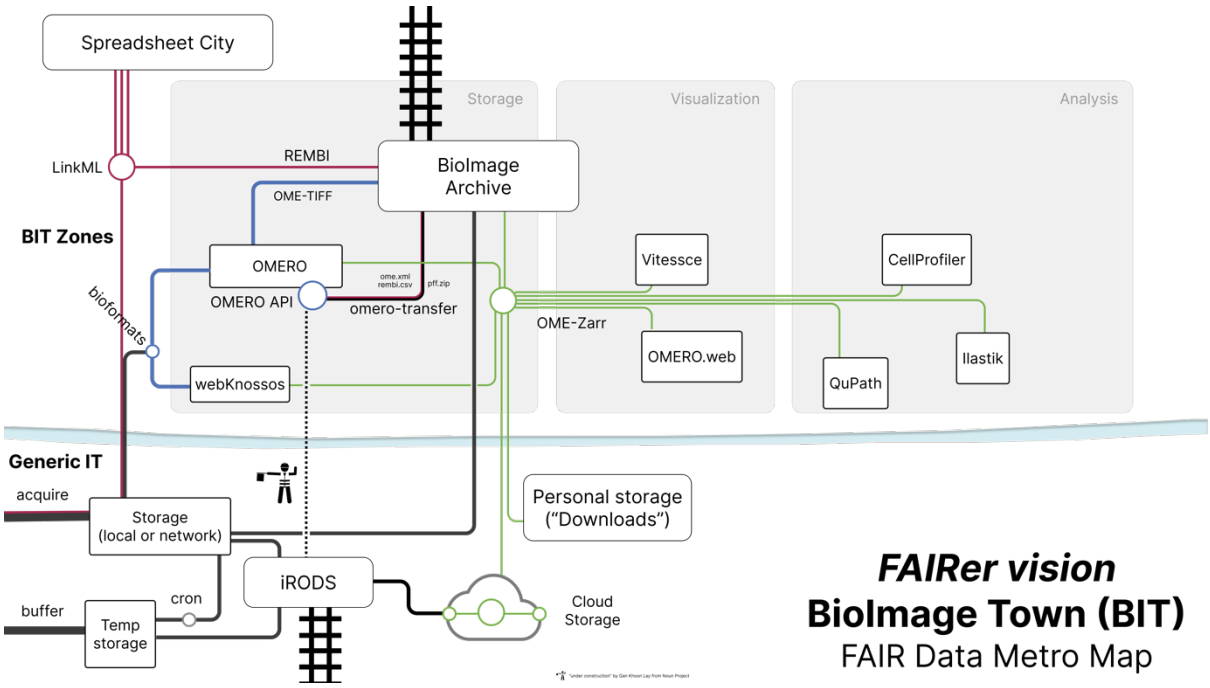

Figure 10. The Bioimage Town metro map. Figures were created collaboratively by the presenters of the Data Management and Analysis session of ELMI2023. **A.** They represent an idealized metro through which data ('the passengers') travel between various solutions ('the stops') within bioimaging ('BioImage Town'), connecting to IT solutions, metadata, and other areas. Red lines represent experimental metadata; black lines represent acquired images; visualization, sharing and analysis through public domains is shown in blue lines, and further analysis and re-use is shown in green lines. **B.** This panel shows specific tools related to each of the aforementioned steps of the FAIR Data Metro Map, emphasizing the value of OMERO, the BioImage Archive, the need for cloud storage, and the value of software such as CellProfiler, QuPath and Ilastik.

Caterina Strambio-De-Castilla highlighted the fact that metadata is essential for data organization, quality control and FAIR sharing. Metadata is data describing the data, namely, for microscopy, this represents all the information that is needed for interpretation and evaluation of the images obtained. Ultimately, metadata makes it possible to evaluate the quality of the information acquired, and to know all the specifications that make the images both reliable, and reproducible. Metadata also makes it possible to track information and communicate between researchers and core facility managers. Important steps to bring FAIR into practice include contributing to databases taking into consideration sample preparation, image acquisition, and image analysis. Caroline identified fragmentation as a key problem in metadata management, but mentioned as an example that NIH Data Collection is contributing to a better integration. International efforts towards metadata management will be vital in the near future, and include consolidating all the information including materials and methods, instrument characteristics, calibration, quality control metrics, and image analysis pipelines. Caroline Miller emphasized the importance of image metadata for data organization, quality control and FAIR sharing, using as an example a biopharmaceutical workflow. In the context of a pharmacology project, an experiment can span multiple departments and teams within an organization. Therefore, obtaining consistent and valid data and the associated metadata starts with adequate planning and optimal communication between the various teams. Correlation of imaging data with orthogonal experiments from other disciplines is key, as it increases confidence in the project results and its conclusions. In inter-disciplinary, multi-team settings, good communication between the team, as well as clear experimental design and good documentation is essential. For this, it is key to know what kind of data is needed (either qualitative, quantitative or both), what type of image analysis needs to be done, and what experimental design is best for the research hypothesis. Altogether, all

the speakers agreed that the relevance of metadata in imaging must be further emphasized and its importance communicated to researchers across disciplines.

Impact

The final session of the day focused on the impact being made by four BINA members from across Canada, Mexico and the US. Michael Almeida and Gastón Contreras Jiménez exemplified the impact being made in education and training while Aurelie Cleret-Buhot and Frederic Bonnet highlighted the impact in metrology and instrument quality control. Their main conclusions are summarized in **Figure 11.**

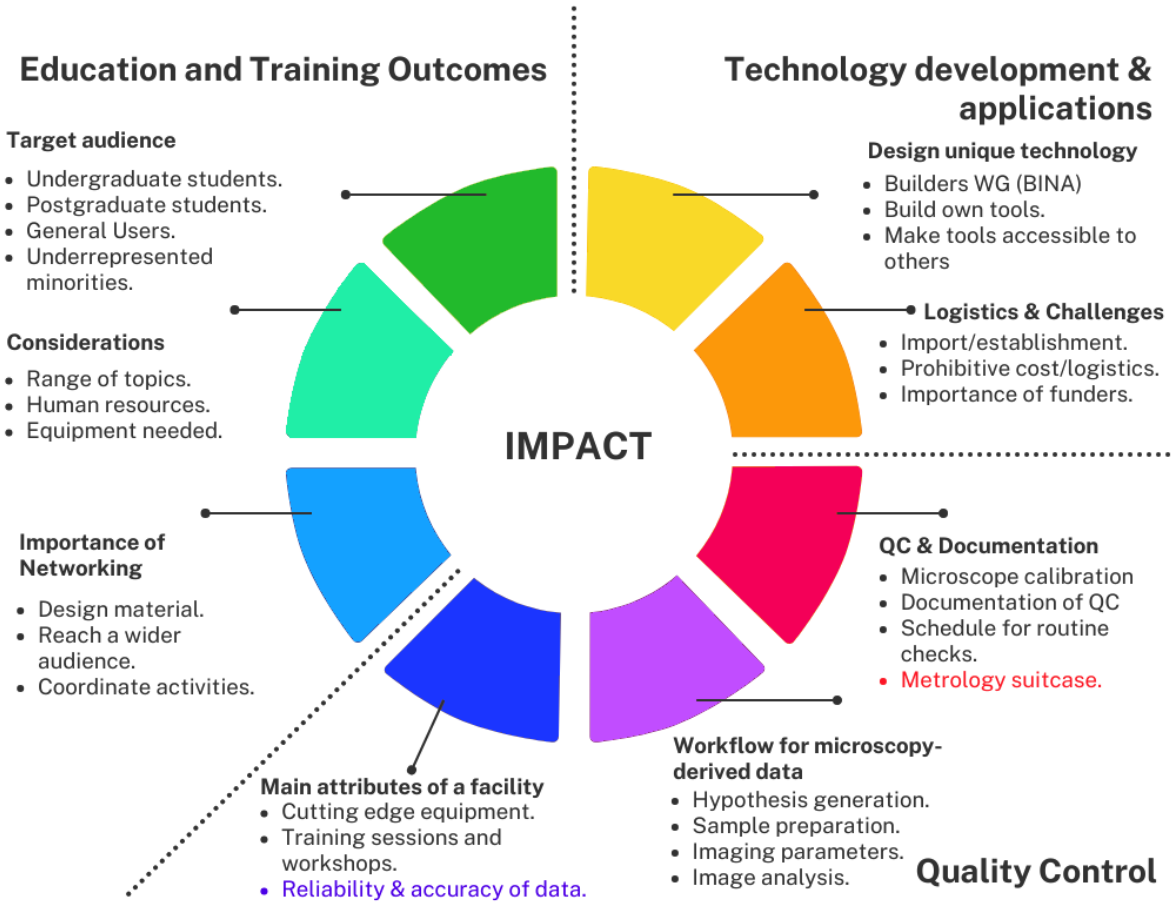

Figure 11. Summary of discussion on the measurement of impact in core facilities. The impact of core facilities can be measured through training and education outcomes (both within the institution and national and international engagement); through quality control of the instruments; and through the development and dissemination of novel technology. Image created with Canva.

Education and training outcomes

Michael Almeida began by making an analogy: there is a difference between using a cell phone, and being an expert in its functions. Sometimes, using a microscope is like using a cell phone: you may know basic features, but not the entirety of the functions, nor the electronics and physics behind its operation. However, in order to gain further expertise, one must be prepared to accomplish this through training and education. Although knowing all the features of a microscope

is not necessary, it is important to know who can provide help when needed. Michael first became involved in BINA as a recipient of Professional Development support to attend the OMIBS course at Molecular Biology Laboratory (MBL), Woods Hole. He took what he learned at OMIBS and hosted an Optical Microscopy and Imaging Training course at his home institution of University of North Carolina (UNC)-Pembroke USA, where there is an important focus on undergraduate students from underrepresented groups to learn microscopy. Next, and within the scope of education and training outcomes, Gastón Contreras Jiménez, leader of the Laboratory of Microscopy and Laser Microdissection at UNAM, Mexico presented the outcomes of the Mexican Bioimaging Workshop V program organized by him and Ruth Rincón Heredia. The program focused on optical and electron microscopy, advanced techniques and laser microdissection. Gastón began by asking the audience how many people had had the chance to organize a workshop, to which a minority of participants replied affirmatively. He proceeded to highlight key features to consider when organizing a workshop: the range of topics to be taught; the human resources needed and the equipment required. He emphasized that doing virtual demonstrations is no routine task, since in order for this to be truly inclusive, it requires a complex setup to capture a complete visualization of the practical activities. He also presented a book, an outcome of this Workshop published in an Open Access repository of UNAM. Gastón concluded by emphasizing the importance of networking and collaborations, introducing Armando Burgos Solorio from the Bio-Arthropods Bioimagen México group whose astonishing insect images and sculptures decorated the meeting spaces and whose moving video shed light on the disappearing culture and language of the Naha people of Mexico. Gastón also emphasized the importance of engaging in outreach to the next generation of microscopists, in order to sustain this rich research field.

Quality control and the metrology suitcase

Frederic Bonnet discussed how quality is ensured at the Mount Desert Island (MDI) Biological Laboratory light microscopy facility. The main attributes of the facility are cutting edge microscopy equipment, personal training sessions and workshops, and reliability and accuracy in data. They endeavor to teach microscopy in a way that it ensures complex understanding of the workflows needed for microscopy-derived data, including hypothesis generation, sample preparation, imaging parameters, and image analysis. Essential to the publication of microscopy-derived data is reliability and accuracy during image acquisition. Part of the quality control for this is the use of standards and patterns to calibrate microscope function in both 2D and 3D. The documentation for quality control (QC) includes a complete report for each microscope, a simplified version on GoogleDocs for the users, and good records of maintenance. It is important to implement a maintenance schedule with routine checks to ensure proper function of the equipment, and to meticulously document the result of such checks in logs. The guideline for users prior to publication includes overseeing that the checklist of essential imaging guidelines for publication is complete, providing customized templates and files with microscope-specific information, and adding essential information on doors where microscopes are housed. Also in the context of quality control, Aurélie Cleret-Buhot discussed the BINA metrology suitcase program, modeled on a CNRS (Centre National de la Recherche Scientifique) initiative for multidimensional optical fluorescence microscopy (Réseau Technologique Microscopie de Fluorescence Multidimensionnelle (RTmfm)). The suitcase, for which Aurélie is the host in Canada, includes tools for light source intensity/stability measurements and point spread function / resolution analysis. Aurélie, along with the other 4 suitcase hosts across North America are currently beta-testing the tools and protocols in the case to ensure that it is user-friendly and straightforward to use once the 'traveling portion' of the program is deployed. The protective hard-shell case includes a PSF check slide, a TetraSpeck fluorescent microspheres kit/slide, a power meter with microscope slide power sensor, and protocols to conduct the QC steps. The intention is to provide facilities with the protocols and tools they need to QC their microscopes without necessarily having to invest in such tools first, and to make data collection as uniform as possible between different facilities. It will also be

possible to upload the data to a centralized repository organized by QUAREP-LiMi to track instrument quality over time, help better understand common quality issues and help determine optimal instrument QC frequency. Important impacts of the metrology suitcase initiative for the facilities include the ability to follow up on the instruments in an organized fashion; monitoring in order to prevent major problems; providing a tool for quality control and reproducibility; and being a link to the community, including providing help when required.

Technology development and applications

The final session of the BINA meeting focused on technology development and applications, particularly on the philosophy of removing barriers to transitioning new technology into the hands of the users. Talks were led by Abhishek Kumar (MBL, USA), Reto Fiolka (UT Southwestern Medical Center, USA), Anita Mahadevan-Jansen (Vanderbilt University, USA), Shalin Mehta (CZI Biohub San Francisco, USA), and Alenka Lovy (Universidad Mayor, Chile), with Kevin Eliceiri (UW-Madison and Morgridge Institute for Research, USA) as moderator.

With the aim of democratizing access to advanced technologies, MBL's imaging initiative is based on the joint efforts of the people involved in developing tools and those performing biological research, to make sure technological barriers are well-identified, that the right tools are designed in response to this need, and making sure that the tools are working as expected. Several next-generation instruments designed at MBL were highlighted, each of which have multiple active collaborations worldwide and various labs replicating the designs elsewhere. These include a line scanning confocal microscope with double objectives, the parts of which are recyclable and editable to add custom-made features that address specific research needs, and a ring-total internal reflection fluorescence microscope designed to be more accessible and cost-effective. In view of the importance of training imaging scientists in building their own tools, the formation of a 'Builders Working Group' was introduced. The aim of this group is to organize events relevant to microscope design; to set up a webpage and other online tools that facilitate sharing and designing tools, generating 3D models, and providing a platform to share relevant information with the scientific community; reaching a consensus on microscope design; and providing a forum for continued discussions. Under this same umbrella of unique technologies, Reto Fiolka spoke about oblique plane microscopy, a type of light-sheet microscope, which uses a single primary lens for illumination and detection. This forms a versatile 3D imaging platform that enables the collection of more light from the specimen, taking advantage of changes in refraction index, tilting and incidence angle. Different applications of this technology include the study of immune and cancer cells interactions, in particular, cell ruffling by seeing traction on the surface of the cell and what causes the ruffles. Moreover, oblique plane microscopy can be combined with structured illumination microscopy (SIM) to create a rapid yet sensitive volumetric super-resolution modality. Further, OPM lends itself for projection imaging, which enables rapid volumetric interrogation. Anita Mahadevan-Jansen focused on label-free multimodal microscopy approaches to study dynamic biophysical processes. Label-free approaches allow the visualization of novel dynamic processes that were previously unknown. MANTIS is a Multimodal Advanced Nonlinear and Thermal Imaging System, which works in infrared wavelengths and this results in better resolution and imaging characteristics when studying at depth in biological tissues. An example of this method is the study of cervical remodeling, for instance, *in vivo* Raman spectra can be acquired in mouse models, while *ex vivo* analysis can be performed using MANTIS to observe changes in collagen fiber alignment, elastin density, blood vessel diameter and nuclear density. A major challenge of this system is the amount of data that can be acquired, namely, one session can produce 15TB of data. To overcome this challenge, they have created a local fiber network. As part of their commitment to removing barriers, the Biomedical Microscopy, Immersion,

Innovation, and Discovery (BioMIID) at Vanderbilt University promotes collaborations to use their instruments including MANTIS, Lattice Lightsheet Microscope (LLSM), Scanned Oblique Plaque Illumination (SOPi) microscope, multi-photon (MP)-SOPi, and Meso-Micro, and they have started a visitor imaging program to allow researchers to directly access BioMIID.

Shalin Mehta, representing the CZI BioHub in San Francisco spoke about the importance of deploying computational Microscopy. He highlighted the importance of mathematical modeling for the useful interpretation of data. Inverse models allow the reconstruction of images from data to original images again. However, the information that can be extracted includes unique features such as density, orientation, shape, architecture, etc. For example, density information can be obtained from defocus because the density of materials that light passes through affects the intensity of the images. Equally, polarized illumination encodes orientation. A technique that uses this is phase and polarization. Using these tools, the reconstruction of a label-free image allows us to observe intracellular structures that are not differentiable in the original image. These different technologies have been used in Shalin's work to study dynamic emergence of cell states. Other tools used by his team, in combination with computational models, include quantitative label-free with phase and polarization (QLIPP), multimodal instant polarization microscope (miPolScope), uniaxial permittivity tensor imaging (uPTI) and MANTIS, each of which have specific advantages including sensitivity, speed, resolution and sample preservation.

Alenka Lovy, representing LiSIUM, addressed a slightly different topic regarding access to technologies, namely, the challenges of introducing novel technology to Latin America, and the importance of this technology being affordable. She is leading efforts to introduce the Flamingo lightsheet microscope to Latin America, and she spoke about the logistics and work 'behind the scenes' involved in making this possible. These initially included ensuring funding and institutional support, for which CZI funding has been key. But even with these secured, other hurdles were faced including the logistics involved in borrowing a Flamingo microscope and importing it into the country. The necessary documentation includes a transport document, commercial invoice, insurance policy, a certificate of origin, and a catalog number. Due to these hurdles, and the possibility of being charged 100% of the value of the equipment should the process exceed a certain timeline, the less complicated option is to build the Flamingo microscope locally instead. Further aims of this project include having workshops between facilities to exchange knowledge and promote lightsheet microscopy usage, and to organize a conference focusing on lightsheet Microscopy. In this context, Alenka shared her experience in preparing the first LiSIUM workshop, and she sent a clear message that institutional bureaucracies are a major barrier to sharing technology, both due to the cost involved, which sometimes has to be paid up-front and out-of-pocket and then await reimbursement, and due to the logistical requirements and a significant amount of paperwork making it prohibitive for a research scientist to organize a workshop. She called for better support and initiatives to tackle these barriers, and ended by inviting the entire community to join the Flamingo and Lightsheet research initiative in Latin America.

Conclusion of BINA meeting

The main program of the BINA meeting was brought to an end with a closing summary that emphasized that different approaches are being used across North America for training and education of technologies, image informatics, core facility management and data management, that there is no 'one size fits all' and that we can and should be sharing resources amongst our communities (MicroscopyDB). The bioimaging community as a whole is facing similar challenges around image analysis and data management so it is important for us to share experiences and invite everyone to contribute to the discussions and finding solutions. Technology developers need

partners to bring their technologies to fruition; users are essential for providing the feedback needed to strengthen and develop the technologies - software and hardware alike - to ensure they are relevant and useful to the biologists. As community networks we are stronger together, raising awareness of shared challenges and supporting each other as a collective and individually through the personal networks we build within communities. With passion and commitment we can work together to tackle the big problems, sharing resources and expertise to improve efficiency, reduce duplication and accelerate scientific progress.

Around 10 participants remained on site at the Hacienda after the official program closed for another offering of the Pop-Up Exchange of Experience hosted by Caterina Strambio de Castillia and Beth Cimini - "Managing the image-data life cycle for the real world: connecting the dots from sample preparation, to image acquisition, analysis and publications". Resources from the full meeting are shared in the supplementary resource section below.

Concluding remarks: the importance of joined network meetings

The LABIxBINA meeting brought together the two largest optical bioimaging networks in the Americas, with over 100 participants from 16 nations in the Americas and abroad. This created the opportunity for all participants to interact with new communities and brought together the expertise and mentorship of experienced scientists with the creativity, energy and enthusiasm of early career scientists. An important result was an inspiring atmosphere and outlook of both bioimaging communities. The idea of organizing a joint meeting such as this is beneficial for many reasons including the following:

- Participants from diverse backgrounds have an opportunity to bring their unique perspectives to a conversation in shaping the future of imaging worldwide.
- Contributions are welcomed from all levels of expertise and experience, allowing participants to share lessons learned, challenges faced and both failures and successes in implementing initiatives. This paves the way to progress in a time- and resource-optimized manner that is based on well-thought out risk-assessments.
- It lays the groundwork for better communication and successful collaborations, as it allows participants to exchange information on technological developments, network structure and organization, professional development, and opportunities for mobility funding and cooperation in the different regions. The result of this aim is to avoid effort duplications and put energy towards new developments and accelerating scientific progress. We aim to report, in the years to follow, information about collaborations and interactions that arise between LABI and BINA members.
- It provides an opportunity for diverse stakeholders to come together. Examples of this during the LABIxBINA meeting included the opportunity to communicate shared successes and challenges to the local academy of science representatives in Morelos, Mexico, and CZI, a funder which has had a vital impact regionally and globally.
- It allowed the community to engage with corporate partners who manufacture instruments, provide image analysis tools and reagents. This allowed the industry partners to better understand the bioimaging communities' successes and challenges. This included discussions on how to overcome those challenges, such as how to acquire and maintain instruments in low resource settings.
- Both networks have been supported by CZI. This meeting allowed both networks and multiple grantees from BINA and LABI to engage with CZI leadership, and show the progress made on the various initiatives, as well as discuss remaining challenges and opportunities. Equally, having shown the tremendous impact that CZI has had in both regions, this was an opportunity to demonstrate to other funders the relevance of community-building and networks to enable high-quality science.

Throughout the event, attendees were able to immerse themselves in the Mexican culture, enjoying local gastronomy, a mariachi musical event, a historical location (Hacienda Vista Hermosa), and photographic displays of local fauna from Bio-Artropods, highlighting the importance of bioimaging for scientific communication and dissemination, and as a way to both, engage local communities, and highlight the cultural heritage of regions around the world. The organizers considered many essential details to make this experience a welcoming and inclusive one for all attendees. Overall, we believe joint meetings are vital for promoting dialogue and initiatives to build a truly global and open microscopy community.

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