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Abstract: Latin America is home to more than 600 million people and has considerable natural and human resources. However, investment in science and technology (S&T) lags far behind that in developed countries. This gap represents a barrier to the development of economies based on knowledge and hampers the region's ability to tackle environmental and social problems. This lack of investment is evident in the extreme case of Venezuela, where much of the science workforce has fled economic chaos, but also in every Latin American country, including science powers such as Brazil and Argentina, where federal budgets in science, technology and education have been drastically reduced in recent years. Investments in S&T foster cooperation, commerce and good will and enhance resilience in the face of environmental and social turmoil. Therefore, scientists must start to actively engage governments and encourage long-term spending in S&T to support the development of Latin American societies. **Word count: 150**

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Main Text:

In Latin America and the Caribbean, education, science and technology (S&T) have rarely taken the place they deserve as indispensable tools to achieve long-term sustainable development and to advance the overall quality of people's lives. This could explain why while the region represents 8.6 percent of the world's population, only 2.5 percent of all scientists come from that Latin America (Inter-American Development Bank, 2007) The topic of S&T may be mentioned briefly during presidential campaigns, but most countries lack policies to stimulate science-driven

development. As in many developing countries, an underlying bias in Latin America holds that S&T are a frivolous expense that is unconnected to development. Political and economic chaos in Venezuela has decimated the science sector; in other countries, an ideological shift to conservatism coupled with cycles of boom and bust have resulted in the current period of generalized fiscal austerity. But we know that strong investment in S&T and development is a trait of the successful and newly industrialized economies in Asia and in established powerhouses such as Japan, Germany and the United States (The World Bank, 2016), which invest 2.5% of their GDP, on average, in S&T (The World Bank,2016). South Korea is now a fully industrialized country and a leader in Science and Technology (The World Bank, 2016).

Moreover, in order to have a strong research system that fosters creativeness and innovation, the S&T environment in Latin America needs to tackle inequality and lack of diversity in science, as few scientists come from either low-income households, or African and indigenous backgrounds (Gevin, 2019). Clear policies are also needed to promote gender equity in the region: even though women are 46 percent of all researchers in Latin America, one of the highest percentages in the world, they still receive low salaries, and are not promoted to decision-making positions (Inter-American Development Bank, 2007; Senacyt, 2018).

In **Argentina**, past President Macri slashed research investment from 0.62% of GDP in 2015 to ~0.3% (estimated value since no official numbers are available) in 2018, with a projected reduction of tens of millions of dollars to only 0.25% for 2019 (Fig. 1). Budget cuts have affected the main national S&T bodies, namely the National Scientific and Technical Research Council (CONICET), national universities, and scientific organizations such as the Industrial Technology Institute, Atomic Energy Commission, Institute of Agricultural Technology, Space Activities Commission and the Argentinian National Company of Satellite and Nuclear Reactors (Noticias Magazine, 2018) (Fig. 3). In many cases, these cuts led to the closure of development and innovation programs, including flagship scientific projects such as the Argentinian Satellite Program and Argentinian Nuclear Power Program. A decrease in the number of projects financed for S&T activities, together with the depreciation of the national currency, have resulted in subsidies that are insufficient to sustain advanced scientific activities. The continuity of planned research agendas and research groups has been placed at serious risk. The few subsidies

researchers have access to now reach maximum US dollar values of ~10,000 per year for entire research teams. Likewise, programs that were funded with international cooperation in mind have been interrupted, which has resulted in the discontinuity of ongoing projects and acute brain drain. Of note, budget cuts in education and S&T were accompanied by increased spending on defence (The Official Newsletter of the Argentine Republic, 2018; El Tiempo Newspaper, 2018).

In the case of **Brazil**, cuts to research by Presidents Temer and Bolsonaro have reached 50% or more since 2016, with loses again mounting to hundreds of millions of dollars. These cuts put at risk Brazil's significant advances across a range of fields. Particularly noteworthy in recent years has been the development of oceanographic technologies for exploring and extracting deep-sea oil and natural gas, transforming Brazil into one of the largest oil and gas producers in the world. The development of a local aeronautic industry due to efforts by the Technological Institute of Aeronautics and EMBRAER (Brazil's aircraft manufacturing company) made Brazil an important player in the aircraft production industry. Other important examples are the development of a strong agricultural sector, especially in soybeans for export to China, and the construction of Sirius, a 4th-generation particle accelerator (Fig. 3). In biomedical research, important discoveries have been made to combat HIV and Zika virus. This legacy is now in danger (Brazilian Society for the Advancement of Science, 2018). In 2018, the National Council for Scientific and Technological Development (CNPq) operated with a budget deficit of R$85 million (about $20 million); nearly 5,000 research projects that had already been approved could not be funded (National Congress of Brazil, 2018). This situation led to a 75% reduction in the number of scholarships (National Congress of Brazil, 2018). The general budget of CNPq was expected to be further decreased (14%) (National Congress of Brazil, 2018). Additionally, the acclaimed program Science without Borders (CsF), which invested almost R$1.9 billion ($0.4 billion) per year for seven consecutive years to develop collaborations with well-established groups abroad, was abolished (National Congress of Brazil, 2018). In March 2019, the Bolsonaro government announced a new 42% budget cut for the Ministry of Science and Communications, and a 30% cut to all federal universities (de Oliveira, 2019). Although final numbers for the year 2019 are not yet available, it is public that the situation for universities already worsened dramatically, surpassing the most pessimistic forecasts. All of these cuts have resulted in an extremely uncertain research scenario that resulted in the abandonment of researchers and of research lines relevant to the

country's development (de Oliveira, 2019). To make matters worse, relaxation of environmental regulations and indigenous reserve protections during the Bolsonaro regime have resulted in an increase of deforestation rates (>50% than last year) and forest fires (>80% than last year) in 2019, threatening conservation efforts in the world's most biodiverse country (Escobar, 2019; Gibbens, 2019).

When considering the eradication of poverty, one of the Sustainable Development Goals (SDGs) proposed by the UN, Brazil is ranked 79th/189 in Human Development (HDI), with 13.2 million people living in extreme poverty. According to Oxfam, Brazil holds the second place in the world with the highest income concentration within the richest 1% (OXFAM, 2019). However, the current Brazilian government has cut the budget of social programs for 2020, reducing resources to the poorest communities and perhaps stunting human development for years to come.

In relation to agricultural sustainability, most agricultural activities are threatened as the Amazon helps regulate regional climate via evapotranspiration, which directly affects regional rainfall (Spera et al., 2016).

Mexico's universities have greatly contributed to Earth sciences, physics, material sciences and electronics. One example is its famed National Laboratory of Genomics for Biodiversity (Langebio) (Fig. 3). Unfortunately, Mexico's federal government is currently facing a deficit and may resort to budget cuts to achieve a 1% surplus for 2019 (Mexico News Daily, 2019). Mexico's national council for S&T (CONACYT, in Spanish) has seen its budget cut by 6.5% (Mexico.com Newspaper, 2018). Cuts to salaries at its largest research universities have been announced despite President López-Obrador's pledge to support S&T (Mexico.com Newspaper, 2018). Approximately 100 000 university employees went on strike during October 2019 to protest the bankruptcy imposed by the federal government on nine state universities, which means that wages are not being paid and that some universities will close by the end of the year (Lobo, 2019). Though Mexico is a relatively wealthy middle-income economy, industrial productivity remains low.

Chile has made great contributions to Earth sciences, mathematics, physics, astrophysics, biology and biomedicine. Nonetheless, it has historically invested only about 0.4% of its GDP in

S&T (The World Bank, 2016) (Fig. 1). This amount is mostly invested by the state, and research is mostly carried out in universities (OECD, 2018). The Ministry of Science, Technology, Knowledge and Innovation was created only recently (National Library of Congress of Chile, 2018). Despite positive expectations regarding its creation and the establishment of long-term policies for S&T in the country, to be successful these will require a significant increase in public investment in science. However, there is also the risk that the ministry might reduce the effective budget for research grants given the administrative costs of running this new institution. Two of the main problems in Chile are the low rate of approval of scientific projects due to the strong increase in applicants and the lack of positions for young scientists at universities and research centres. Undoubtedly, this situation will jeopardize the development of scientific careers especially for young researchers, who face serious financing difficulties at the start of their careers. Regarding the current situation of social unrest, it is believed that a strong investment in science may facilitate the correction of social injustice, and help address other pressing problems such as water scarcity, desertification, and the accelerated ageing of its population (Hidalgo, 2019).

Colombia has developed scientific strengths in immunology, physics and environmental sciences. One example is its Optics and Photonics Laboratory at Antioquia University (Fig. 3). However, only 0.24% of Colombian GDP is invested in S&T, 15 times lower than the OECD members average (The World Bank,2016). Colombian S&T investment is only a fraction of Mexico's (La República Newspaper, 2017). Compounding this problem, Colombia ranks last in education investment among Latin American countries, reaching only 10% to 20% of the investment by others in the region (El País Newspaper, 2017). Protests have intensified during 2019 as a response to poor funding to universities and proposed privatisation of pensions, reduction of the minimum wage for young people and an increase in energy tariffs (Franz and Gómez-Suárez, 2019).

Costa Rica has built the only nuclear fusion reactor in Central America (IAEA 2018) and its only medical cyclotron (Semanario Universidad Newspaper, 2019) (Fig. 3). It has also developed its own technologies for antibody production and blood plasma storage (Semanario Universidad Newspaper, 2018). Nonetheless, only about 0.4-0.6% of its GDP is invested in S&T (The World Bank, 2016) mainly through public universities (95%) (OECD, 2018), in strong

contrast to the nearly 2.5% GDP average investment by the 36 countries of the Organization for Economic Cooperation and Development (OECD) (OECD, 2018). Private spending in science is low even compared with other Latin American OECD countries, in which at least 30% of spending is private (OECD, 2018). But facing a budget deficit of 7%, the current administration has cut the overall budget of public universities and is moving to cut university staff pay (La Nación Newspaper, 2019). The Constitutional Court has ruled that efforts to reduce spending on education are unconstitutional (Delfino, 2019).

Panama has been historically known research in biodiversity and tropical diseases, conducted mainly by the Smithsonian Tropical Research Institute, an US-institution based in Panama, and by the Gorgas Memorial Institute of Health Studies, first run by the US government but managed by Panama since 1990. The National Office for Research, Technology and Innovation (SENACYT in Spanish) was created in 1997, and its programs have allowed for an increase in the number of Ph.D. holders and in scientific publications. However, Panama has been spending less than 0.1-0.2% of its GDP in S&T, a proportion far lower than that of Sub-Saharan countries (La Prensa Newspaper, 2019). This amount is mostly contributed by the government. It is believed that a strong increase in investment S&T is required in order to tackle Alzheimer disease, ageing as well as neglected tropical diseases (La Prensa Newspaper, 2019). Newly elected President Cortizo has promised to increase the investment in S&T to 1% of GDP within the next five years (La Estrella de Panamá, 27/03/2019), a situation unique in the whole continent.

For decades, **Venezuela** made significant contributions to medicine, chemistry, biology, petrochemical processing, physics, mathematics and various engineering disciplines. Today, overwhelmed by political and economic crisis, the country is struggling through one of the worst moments in its history (Fraser, 2016). The effects on science are profound: In 2014, Venezuela had an estimated 12,850 researchers; now only about 3,000 remain (Requena, 2016). This brain-drain resulted in a strong decrease in scientific productivity (> 50%) according to figures from SCImago Journal & Country Rank. With the ongoing economic and social collapse, an estimated 10% of the population left the country in 2018, and many scientists have requested refugee status abroad. The development of local industries focused around food processing, and the manufacture of radiopharmaceuticals and blood-derived products, have stopped altogether. Poor funding

(0.12% of GDP as of 2016) (Requena, 2016), aggravated by hyperinflation and frequent blackouts, result in empty laboratories, deteriorating equipment and run-down infrastructure. Students and faculty are deserting the country. Venezuela's science sector is collapsing.

As for the rest of Latin America and the Caribbean, data are scarce. In Peru, there was no Internet access at all to scientific journals in 2016 (La República Newspaper, 2017). Peru only spends about 0.1% of its GDP in S&T (UNESCO, 2015), and Dr. Gisella Orjeda, the former president of Peru's National Council of Science, has mentioned that poor resource allocation may have contributed to chronic and severe brain-drain (Bajak, 2019). Also located in South America, Ecuador is a country that spends 0.4% of its GDP in S&T (UNESCO, 2015). In 2019, civil unrest caused by austerity measures agreed by President Moreno with the International Monetary Fund (IMF) seriously disrupted work at universities (Cozzarelli, 2019; Medina, 2019).

According to several sources, including UNESCO (Fig. 2), as of 2015 investment in S&T as a percentage of GDP in Central America is as follows: Cuba (0.4), El Salvador (0.13), Nicaragua (0.11) (Fig. 3), Guatemala (0.03), Honduras (0.02) and Belize (no data) (The World Bank, 2016). In the poorest of these countries, science may remain stunted by pervasive violence, economic weakness, high inequality and massive emigration. Scientific cooperation within Central America and the Caribbean is extremely rare.

Concluding remarks

On average countries in Latin America and the Caribbean invest only 0.3%or less of their GDP in S&T (Fig. 2). This investment is in clear contrast to countries with a high degree of human development, which invest close to 3% of their GDP in S&T: Japan (3.2%), Sweden (3.2%), Denmark (2.9%), Finland (2.8%), Germany (2.9%) and the United States (2.7%) (The World Bank, 2016). In Asia countries such as South Korea, that were poor agricultural societies 50 years ago, spend close to 7% (The World Bank, 2016). We believe that after years of uneven but encouraging progress, many governments in Latin America are now engaged in policies that are destructive to science, education, social advancement, the environment and gender inclusion. Gender exclusion in Latin America is particularly acute in engineering, and it is believed that at the current rate gender parity will be achieved in 150 years (López-Aguirre, 2019). Budget cuts to education and research in Latin America may perpetuate low productivity and stunted economic growth as the skills of future workers will not match the needs of advanced production systems.

The region desperately needs to address medical, agricultural, energy and environmental issues, and these efforts require an *increase* in scientific investment, not the opposite. We also believe that low investment may lead to a weakening of regional cooperation networks, which are necessary for harmonious and integrated development, especially considering that bitter border and political disputes between countries are common. A concerted effort that transcends political ideologies is urgent.

Dr. Bernardo Houssay, an Argentinean Nobel Laureate in Medicine in 1947, advised that "rich countries are rich because they dedicate money to scientific-technological development, and poor countries continue to be poor because they do not. Science is not expensive, what is expensive is ignorance." In this context, we advocate a bold new vision: Our societies need to design new strategies for a sustained investment in S&T that can lead to an improvement in regional innovation and cooperation. Without this investment, economic and social development will slow, societal turbulence will worsen (The Guardian, 2019), environmental degradation will be extreme, and we will not achieve the enormous potential of our countries and our people.

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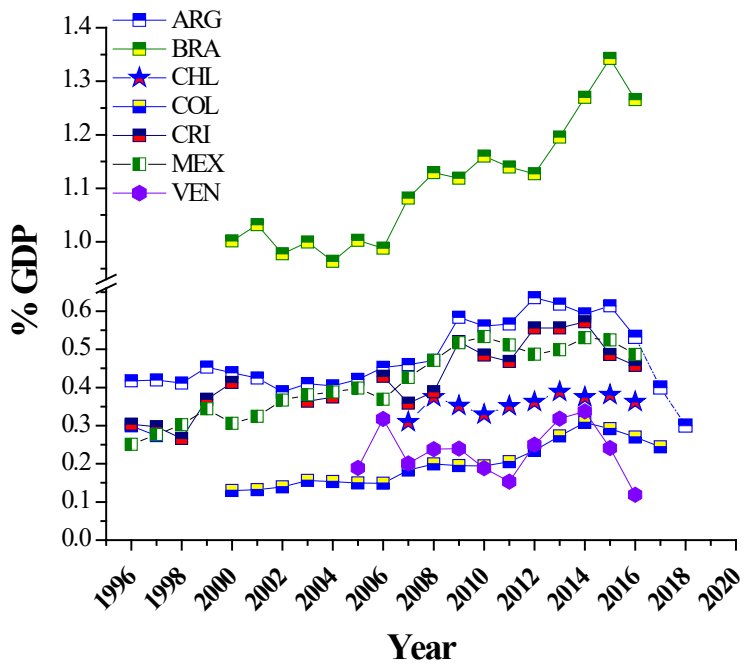

Fig. 1. Investment in science and technology in Latin America (1996-2015, from the World Bank). Blue-dashed line for Argentina represents estimated values according to unofficial data. Since 2016, the Argentinian government has not provided official data.

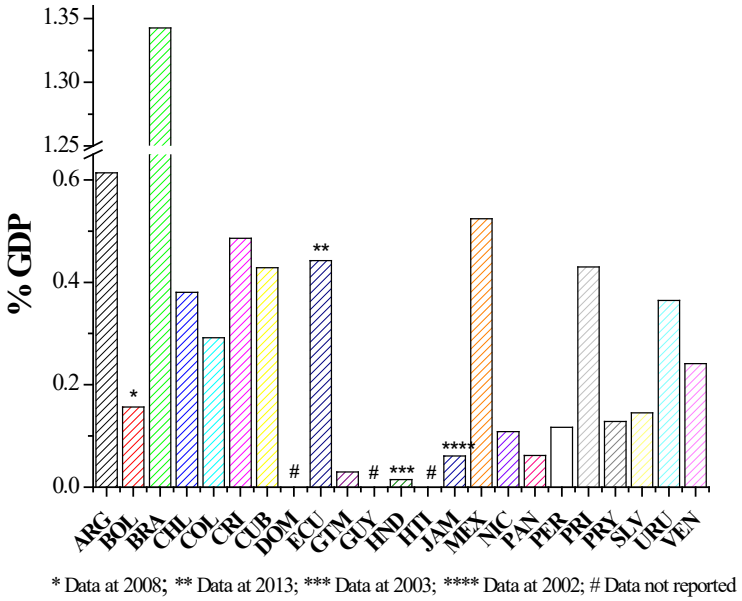

Fig. 2. Investment in science and technology in Latin America and the Caribbean (data as of 2015, from The World Bank, 2016).

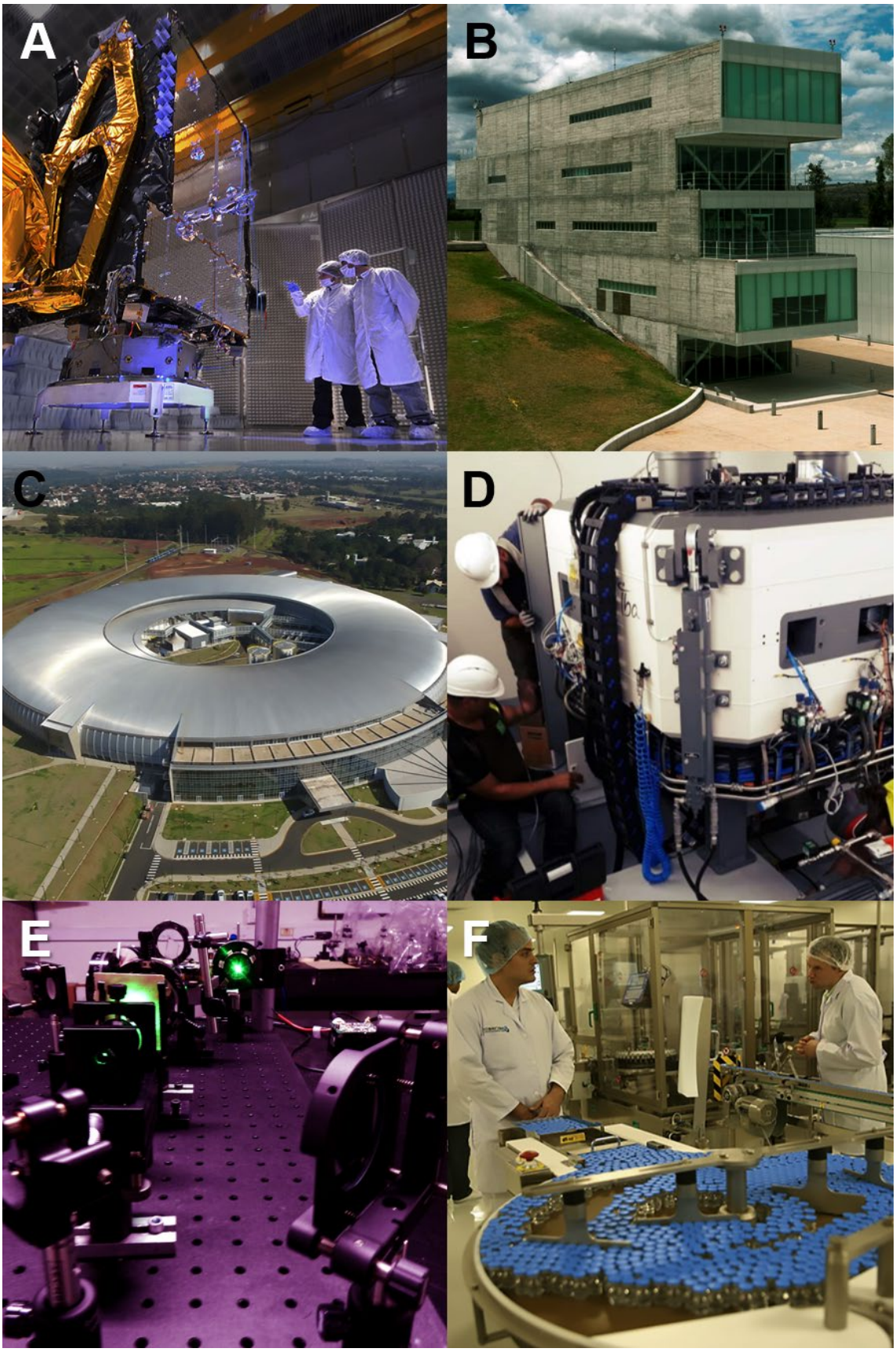

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Fig. 3. Landmark scientific initiatives in Latin America and the Caribbean. A) The Argentinian ARSAT-2 satellite (image courtesy of INVAP Argentina), B) The National Laboratory of Genomics for Biodiversity (Langebio) at Irapuato, Guanajuato State (image courtesy of TEN Arquitectos: LANGEBIO/TEN Arquitectos 2005-2010, Luis Gordoa for TEN Arquitectos), C) The Sirius Synchrotron Light Source in Campinas, Sao Paulo State, Brazil (image courtesy of LNLS/CNPEM, Brazil), D) The Cyclotron at the University of Costa Rica, Rodrigo Facio campus (image courtesy of Dr. Ralph Garcia), E) The Photonics Laboratory at the Antoquia University in Medellin, Colombia (image courtesy of U. of Antioquia), F) The Mechniknov Vaccine Manufacture Plant in Managua, Nicaragua (image courtesy of 19 Digital, Nicaragua). All images were sourced with permission from the respective institutional websites.