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Ismael Clark Arxer

6 · Cuba

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INTRODUCTION

The Republic of Cuba is an archipelago comprising a main island and more than 4000 smaller islands and keys, for a total land area of 109 886 km^2 and a population of roughly 11 million. Cuba is located in the Caribbean Sea just south of the Tropic of Cancer. Its immediate neighbours are the Bahamas, Haiti, Jamaica, Mexico and the USA.

The youngest Hispano-American republic, Cuba was founded in 1902, after a 30-year war of independence against Spanish rule which ended in a four-year occupation by US troops in 1898. During the first half of the 20th century, Cuba was heavily controlled by foreign interests within a plantation and extractive economy. A report by the *ad hoc* Truslow Commission of the International Bank for Reconstruction and Development, which had travelled to Cuba to study the provision of loans, stated unequivocally in 1950 that 'in the field of applied research and labs, there was no development at all in Cuba' (Sáenz and García-Capote, 1989).

Just months after establishing a revolutionary government, President Fidel Castro made his first science policy statement in January 1960. 'The future of our country has to be necessarily a future of men [and women] of science, of men [and women] of thought', he said, 'because that is precisely what we are mostly sowing; what we are sowing are opportunities for intelligence' (Castro, 1960).

This has been the cornerstone of Cuba's scientific development ever since. Following the revolution, the development model evolved into a state-planned economy with education and scientific development as high priorities. Most of the research centres in Cuba today were born of research groups, or started out as institutes, in the decades immediately following the Cuban revolution in 1959. Some of these centres, like the National Centre for Scientific Research (CENIC) founded in 1965, played an essential role in training young science students at home and in the eventual establishment of many other research institutions.

By the dawn of the 21st century, Cuba was perceived as being a proficient country in terms of scientific capacity, despite having experienced more than four decades of a trade embargo and restrictions on scientific exchanges imposed by successive US administrations (Jorge-Pastrana and Clegg, 2008). In a study commissioned by the World Bank in 2001, Wagner *et al* of RAND, an S&T think tank in the USA, classified nations into four categories according to their scientific prowess: developed, proficient, developing and lagging. In Latin America and the Caribbean, only Brazil and Cuba qualified as 'proficient'.

Cuba is still recovering from the effects of the severe economic crisis caused by the collapse of its main trading partner, the Soviet Union, in the early 1990s: GDP dropped by about 40% in less than five years and new markets had to be found for up to 75% of foreign trade, under very difficult credit conditions.

Figure 1 shows a sustained, if modest, increase in Cuba's GDP between 2003 and 2007. The result is that the country's GDP, both overall and per capita, is now on a par with levels at the end of the 1980s. Today, Cuba ranks among medium-income countries. It is interesting to note the growth in the percentage of GDP contributed by community, social and personal services: this grew from 25.5% in 2002 to 34.5% in 2007. Cuba has also diversified its economic ties. In 2006, its main foreign trading partners were Venezuela, China, Spain and Canada, in descending order.

Figure 1: Growth in Cuba's GDP and per-capita GDP, 2003–2007 (%)

Source: ONE (2008) *Statistics Yearbook 2007*

Schoolchildren discovering a telescope

Photo: © Oscar Álvarez/ Cuban Academy of Sciences

ORGANIZATION OF RESEARCH

In the mid-1990s, a Ministry for Science, Technology and Environment (CITMA) was established with the aim of harnessing Cuban scientific knowledge to a more sustainable form of development. The ministry encompasses a dozen science centres of national interest; some of these are among the best in the country, like the Institute of Meteorology (Table 1). There are subordinate executive offices in each of the country's 14 provinces, as well as co-ordinators for the 169 municipalities.

In 1996, the Cuban Academy of Sciences was reorganized. After 35 years of working mainly as a support body for research and development (R&D), the members agreed to new statutes allowing the academy to return to its traditional role of primary scientific advisory body. The institution is now also responsible for recognizing excellence in research and for acting as the representative of the Cuban scientific community, both in Cuba and abroad. The academy has a very long tradition. It was one of the first merit-based national academies of science to be established outside Europe, in 1861, even though it languished for most of the first half of the 20th century for the reasons evoked above.

Table 1: Cuba's top 20 S&T research institutions*

Centre of Pharmaceutical Chemistry	www.cqf.sld.cu
Cuban Institute of Sugar Cane Derivatives	www.icidca.cu
Institute of Animal Science	www.ica.inf.cu
University of Havana	www.uh.cu
Centre of Genetic Engineering and Biotechnology	www.cigb.edu.cu
Institute of Tropical Medicine Pedro Kourí	www.ipk.sld.cu
Havana Technological University José A. Echevarría	www.cujae.edu.cu
Institute of Cybernetics, Mathematics and Physics	www.icmf.inf.cu
Centre of Molecular Immunology	www.cim.sld.cu
Finlay Institute (vaccines R&D)	www.finlay.edu.cu
Las Villas Central University Marta Abreu	www.uclv.edu.cu
National Centre for Plant and Animal Health	www.censa.edu.cu
National Centre of Scientific Research	www.cnic.edu.cu
National Institute of Agricultural Science	www.inca.edu.cu
Bioplants Centre – Ciego de Avila University	www.bioplantas.cu
Cuba Neuroscience Centre	www.cneuro.co.cu
Institute of Plant Health Research	www.inisav.cu
National Institute of Economic Research	www.inie.cu
Institute of Ecology and Systematics	www.ecosis.cu
Institute of Meteorology	www.insmet.cu

*Measured in terms of the number of prizes awarded by the Cuban Academy of Sciences over 1997–2006, on the basis of the number of papers published, the socio-economic benefit of a research result, etc.

Source: author

An overall *National Plan for Science and Technology* is prepared each year by CITMA. The *Plan* is followed up by specialized staff and the accomplishment of objectives and overall progress is periodically reviewed by expert groups organized by CITMA. Priority is given to projects within the National Research Programmes in Science and Technology which have been approved at the highest level of CITMA, according to a peer review process, and which are in turn funded by the state budget. Other ministries select and support sector-targeted S&T programmes in a similar fashion.

An analogous procedure is followed at the provincial level at the demand of territorial authorities. Delegate Offices of CITMA contribute to the selection of local projects and to follow-up processes. These local R&D projects are also funded by the state budget and usually implemented by university research groups or scientific centres located in the territory.

R&D INPUT

R&D expenditure

Gross domestic expenditure on R&D (GERD) in Cuba is more or less on a par with the mean for Latin America and the Caribbean, although regional spending has surged in recent years. The situation is more or less equivalent for overall S&T expenditure (Figure 2).

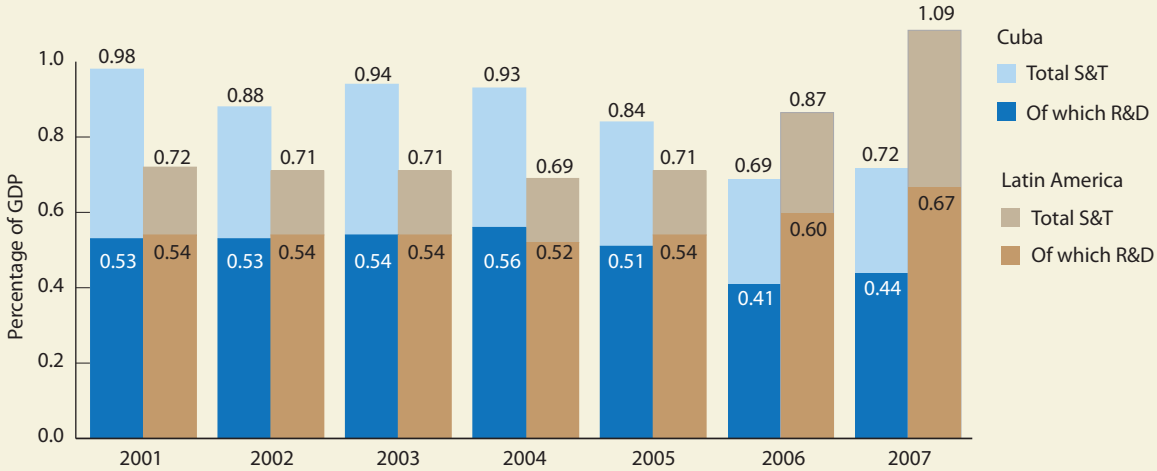
Most R&D projects with a direct link to the immediate demands of the productive sector are funded by enterprises (Figure 3). The share of business funding of R&D has declined in recent years (Figure 4).

Human resource issues

In 2008, 53.5% of all S&T professionals were women. Cuba is second only to Uruguay in Latin America for this indicator, according to RICYT (2010). This proportion will tend to increase, since 60% of graduates entering into a scientific career were women in 2008 (ONE, 2008).

Tertiary education in Cuba today comprises 65 centres of higher education, spread across more than 3500 campuses at the municipal level.

Figure 2: Cuban expenditure on S&T and R&D, 2001–2007 (%)



Source: RICYT (2010) *El Estado de la Ciencia*

First-year enrollment in higher education more than doubled between 2004/2005 and 2007/2008, from 361 845 to 743 979. The social sciences and humanities continue to attract the greatest number of vocations, followed by the medical sciences, with 187 690 first-year students in 2007/2008. A further 42 741 students chose engineering in 2007/2008. Enrollment in the natural sciences and mathematics has remained stable, with 3 970 first-year students in 2004/2005 and 3 922 in 2007/2008.

The total number of graduates has increased each year this century, with an impressive leap in 2007/2008 to 71 475, compared to 44 738 the year before. This performance is largely due to the surge in graduates in health-related disciplines, who numbered 8 396 in 2006/2007 and 24 441 just twelve months later. On the flipside, the number of graduates in the natural sciences and mathematics remains low: they numbered 601 in 2003/2004 and 559 in 2007/2008. Today, there are more than 900 000 university graduates in Cuba, out of a population of 11 million.

Scientists, engineers and technicians are employed in the 119 R&D institutions Cuba counts in its 14 provinces and in 34 other institutions performing S&T services. However, only a small minority (7.3%) of R&D personnel are employed as researchers. In 2006, the work of 7.1 Cubans in every 1 000 was related to S&T in one way or another, a ratio which had dropped to 6.4 by 2007 (RICYT, 2010).

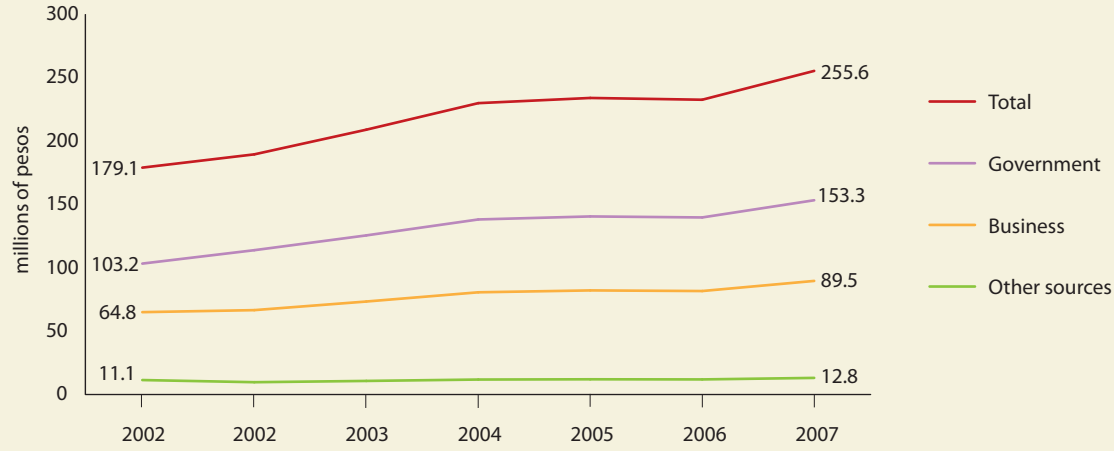
Cuba's National Research Programmes

National Research Programmes in Science and Technology (NRPs) in 2009 are listed in Table 2. Some of these date back to previous periods, as in the case of the Programme for Global Change and the Evolution of the Cuban Environment.

One of the new NRPs is devoted to Information and Communication Technologies (ICTs). In fact, since the end of 2002, computer science has been given a boost with the establishment of a large University of Informatics Science. The main campus is located in Havana, with three branches elsewhere in the country. In 2006, this university reached its designed capacity of 10 000 students, all of whom participate actively in the application of research in informatics to the Cuban economy and society. As part of efforts to spread computer literacy to all those interested to learn and in the perspective of progressive use of informatics in society, a network of local computer clubs has been put in place country-wide since 1990. This scheme has been renewed and duplicated online in the past five years. As of 2009, there were 602 cyber-clubs distributed across the country, interconnected through an Intranet service.

Internet access remains very low, at just 11.6% in 2007 according to the United Nations Statistical Division, although this is a great improvement over the previous year (2.1%). Gradual expansion of access to Internet will be dependent on the conditions under which connectivity can be assured. Expanding connectivity is restricted by the high cost of the

Figure 3: GERD in Cuba by source of funds, 2001–2007

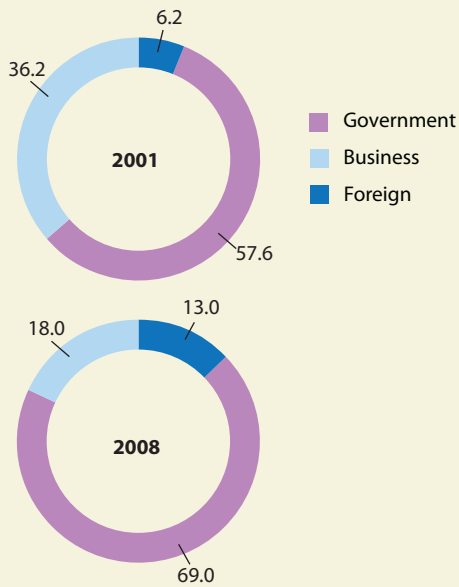


Source: UNESCO Institute for Statistics database, June 2010

satellite channels used – so far, the country's only available possibility. It is also restricted by the refusal up to now to allow Cuba to connect to Internet using an optic fibre cable via either Florida or Mexico, due to the US economic blockade, since both cables are managed by US companies.

Other important NRPs are devoted to neurosciences and to promoting basic research in mathematics, physics and computer science. Yet other programmes deal with previously well-established priorities, as in the case of plant biotechnology and sustainable food production. As a matter of fact, the impact of Cuban biotechnology on agriculture and food production has been significant. Several projects for the development of transgenic plants containing genes for resistance to pests and diseases were under development in 2009. The potential of transgenic plants as systems for the expression of recombinant proteins is being actively explored.

Figure 4: GERD in Cuba by source of funds, 2001 and 2008 (%)



Source: RICYT (2010) *El Estado de la Ciencia*

Social sciences are also part of the NRP. Particular programmes are oriented, for example, towards coping with specific features and problems of Cuban society or in identifying and analysing major trends in the global economy.

The scientific endeavour devoted to energy efficiency and the use of renewable energy sources does not qualify as an NRP but is nevertheless part of a huge State effort to rationalize energy consumption and promote savings. Particular attention is also being paid to the integrated management of water and soil resources, in order to cope with drought and its effects. As a number of projects under this scientific endeavour are considered a priority, they are included in the national S&T budget.

The same goes for nanosciences. The government is beginning to build capacity in this field by providing basic facilities and training personnel. Although nanosciences are not formally recognized as an NRP, some related R&D projects are being carried out within the framework of the NRP devoted to new materials.

Table 2: Cuba's National Research Programmes, 2009

National Research Developments in Neurosciences
Agricultural Production for Food Security
Energy Resources for Sustainable Development
Basic Research in Mathematics, Physics and Computer Science
Information and Communication Technologies
New Materials
The Sugar Industry
Agricultural Biotechnology
Pharmaceutical and Biotech Products
Human and Veterinary Vaccines
Sustainable Development of Mountain Region Ecosystems
Cuban Society: Challenges and Perspectives
The Cuban National Economy
Trends in the World Economy and International Relations
Global Change and the Evolution of the Cuban Natural Environment
Plant Breeding and Genetic Resources
Total: 21 million pesos (US$21 million)

Source: author

The priority given to biotechnology

In the early 1980s, Cuba stepped up its international exchanges. This in turn made it more vulnerable to some epizootics and epidemics. This would mark a turning point in Cuba's commitment to R&D: the combination of these two factors, coupled with the availability of a core human potential, would motivate Cuba to develop the scientific establishment further and expand its base into the national economy. This heralded the beginning of accelerated research in molecular biology and genetic engineering which would culminate in the founding of the Centre of Genetic Engineering and Biotechnology in 1986, one of Cuba's top R&D institutions.

Over a period of 20 years or so, the Cuban government invested around US$1 billion to develop the country's first and most important science node – that of West Havana – comprising of 52 institutions and enterprises related to biotechnology, covering research, education, health and economics. Ten institutions form the core of this node, in that they support the entire effort financially through their production capacities and exports.

In 2008, these 10 institutions were carrying out more than 100 research projects, mainly related to biotechnology applied to human health; these have generated a product pipeline of more than 60 new products. Most of these products are protected by intellectual property rights and more than 500 patents have been filed abroad. Several Cuban scientific results have been awarded the World Intellectual Property Organization (WIPO) Gold Medal.

The case of biotechnology is typical of Cuba's approach to R&D:

- the Cuban government is the source of investment;
- biotechnology is part of the national health system and, for this reason, national needs become a priority;
- success in biotechnology is essentially supported by Cuban scientists and professionals;
- biotechnology follows a 'closed cycle' from research to commercialization by fully integrated state institutions, with profits generated from sales in foreign markets, an important part of which is reinvested in R&D;
- national collaboration replaces competition among individuals as a driving force of Cuban biotechnology;
- 'spin off' state enterprises grow out of scientific institutions;
- success in product development has in turn improved Cuba's ability to access foreign markets, especially in the developed world, in terms of quality, production volumes, cost, novelty and joint ventures (López Mola *et al;* 2006). Two good examples are the licensing agreements signed in 2005 with China's Biotech Pharmaceutical Ltd for the joint development, production and marketing of monoclonal antibodies to treat auto-immune diseases and lymphomas, and, secondly, the agreement signed in 2004 with the American corporation CancerVax for technology transfer in vaccine production from Cuba to the USA to combat malignant diseases.

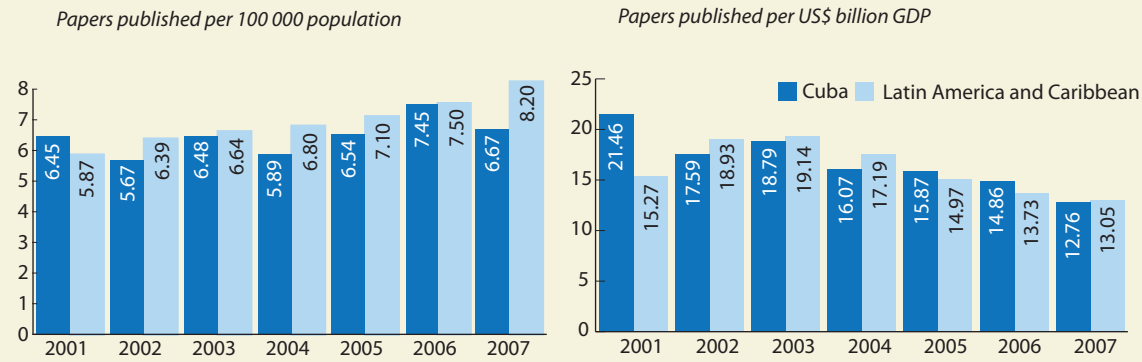
Other R&D piorities

The development and production of pharmaceuticals in general – and biotechnological products in particular – is without doubt the most successful example of the Cuban scientific endeavour but it is not the only area of importance for R&D.

Another important priority today is energy. R&D in this area is mainly related to wind energy production, hydropower, solar photovoltaic and – to a lesser extent – thermal energy from biomass. Generally speaking, priority is given to methods of saving energy and to the efficient use of every energy source.

Cuba began inventorying and evaluating its natural resources and ecosystems some decades ago. A comprehensive report updating the state of the environment was commissioned by

Figure 5: Cuban visibility in international scientific publications, 2001–2007



Source: RICYT (2010) *El Estado de la Ciencia*

CITMA and eventually released in October 2008, following the latest methodological guidelines established by the United Nations Environment Programme (CITMA–UNEP, 2008). More than 70 PhD holders from more than 50 national institutions participated in the study. The report covers such key areas as soils, water resources, biological diversity and the atmosphere; it provides a science-based approach to sustainable management of hydrographic basins, coastal areas and the urban environment, these being considered the main areas on which to focus management by the different authorities involved under the guidance of CITMA.

Disaster monitoring and mitigation is taking on a growing role, in light of the threat of stronger hurricanes, droughts, coral bleaching and flooding in future as a consequence of climate change. An evaluation was under way in 2009 of Cuba's vulnerability to extreme natural events, adaptation to these and mitigation of their effects. Early warning systems are constantly being improved. When Hurricane Gustav, the worst storm Cuba had seen for 50 years, struck on 30 August 2008, followed just days later by Hurricane Ike, approximately 2.7 million Cubans were evacuated. Economic losses totalled an estimated US$5 billion but, thankfully, there were almost no casualties.

R&D OUTPUT

Scientific output in Cuba, as expressed by scientific papers published in international journals, compares favourably with the mean for Latin America and the Caribbean. However, available data show that, whereas Cuba was slightly ahead of the rest of the region in 2001 in terms of papers per 100 000 population, the regional mean has since progressed. If we take the level of GDP into consideration in calculating scientific authorship, the data paint a similar picture for the first few years of the decade. However, both Cuba and the region begin losing ground from 2005 onwards (Figure 5).

Despite this modest numeric output in international publications, the results of Cuban research in several scientific disciplines are of a high quality. In vaccine development, Cuba is even at the forefront of research. One important detail is that these results have a high local social impact; all Cuban children are vaccinated, for instance, against 13 diseases and eight of these vaccines are produced locally.

Among Cuban pharmaceutical products, several should be highlighted. These include: the meningitis B vaccine, a recombinant vaccine for hepatitis B, a recombinant streptokinase thrombolytic agent, the cholesterol-lowering Atheromixol pill, recombinant human erythropoietin and colony-stimulating factors. The list is long. To it has recently been added a proprietary humanized antibody for the treatment of cancer.

In the diagnostic field, networks of neural diagnostics laboratories and ultra-micro Elisa systems (SUMA) for early infant diagnosis, blood safety and epidemiological surveillance have been established and continually improved and expanded since the mid-1980s. These offer coverage for the screening of the entire Cuban population that is unparalleled in the world.

The impact on the population's health is evident: meningitis epidemics have disappeared and hepatitis B is on the brink of being eradicated from the infant population. The entire Cuban population under 22 years of age is immunized against hepatitis B, the incidence of which is the lowest in the world.

INTERNATIONAL RELATIONS

The growing visibility of Cuban science

The visibility of Cuba in the international scientific community has increased somewhat in recent years. In July 2004, the American journal *Science* published a paper on the development at the University of Havana of a synthetic conjugate polysaccharide vaccine against *Haemophilus influenzae* type B. This bacterium is responsible for half of the bacterial infections in children under the age of five, including some of the most feared, like meningitis. In September of the following year, *Science* showcased María Guzmán, head of the virology department at the Tropical Medicine Institute Pedro Kourí (IPK) in Havana and a leading world expert on dengue fever. Guzmán was presented as one of 12 'global voices of science' in an issue commemorating the journal's 125th anniversary.

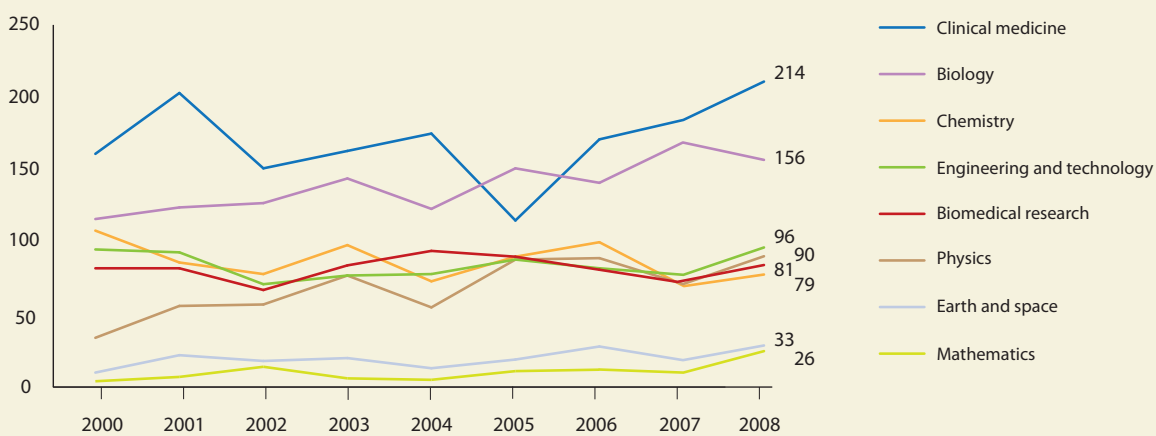
In 2008, the Cuban Academy of Sciences awarded a national prize for the development and commercial production of the first pentavalent vaccine produced in the developing world. The result of close co-operation among several Cuban centres of excellence, this new synthetic vaccine provides protection against *H. influenzae* infections, as well as tetanus, diphtheria, whooping cough and hepatitis B. In December of the same year, *Nature Biotechnology* published a review of the Cuban biotech industry.

Articles written by young Cuban authors in basic sciences are also being published in high-ranking international scientific journals like the *International Journal of Mathematics* and *Mathematical Sciences* (Abreu, 2005). According to data available at Thomson Reuter's Web of Knowledge, Cuban physicists were cited, on average, 60 times per year in 2004–2008, a significant increase. See also Figure 6.

International scientific co-operation

The Cuban scientific establishment is active in international co-operation, through bilateral agreements and by way of participation in international organizations. Bilateral agreements covering a wide range of research topics are in place with Argentina, Brazil, Colombia, Mexico and Venezuela. Beyond the region, China, India and Malaysia are the main partners. Cuba is an active member of the International Council for Science and the InterAcademy Panel for International Issues. It also belongs to regional bodies like the InterAmerican Network of Science Academies and the Caribbean Scientific Union. The embargo has not been effective in preventing international co-authorship of scientific publications, except as concerns co-operation with US scientists.

Figure 6: Publications in Cuba by major field of science, 2000–2008



Source: Thomson Reuters (Scientific) Inc. Web of Science (Science Citation Index Extended) compiled for UNESCO by the Canadian Observatoire des sciences et des technologies

Ongoing medical assistance to developing countries

Cuba also provides medical assistance to developing countries confronted with an emergency. As a typical example, Cuba and Brazil both responded to a WHO request in 2007 to provide the large quantities of doses of A-C anti-meningococcal vaccine required by African countries facing health emergencies. The region at risk is home to 400 million people and covers 21 countries, including Burkina Faso, Ghana, Mali, Niger, Nigeria and Sudan.

Cuban medical co-operation goes back over 40 years but it changed into higher gear with the launch of the Comprehensive Health Programme (CHP) in 1998. This began as an emergency response to the international appeal for help formulated by the presidents of Central American countries devastated by Hurricane Mitch. Gradually, CHP developed into a regular assistance programme for Central American and Caribbean countries. At the request of their governments, the geographical scope of the programme was later broadened to include some African countries. As of 2009, Cuban collaborators working for the CHP had provided medical care to 95.4 million people and performed surgery on more than 2.2 million patients. At last count, Cuban personnel had vaccinated 9.4 million people.

CONCLUSION

By harnessing S&T to social needs over the past 40 years, Cuba has managed to eradicate illiteracy, extreme poverty, hunger and infant deaths due to preventive diseases. Today, the country ranks 51st in the UNDP's Human Development Index, placing it among countries with high human development (UNDP, 2009). Cuba's level of development is considered as being on a par with that of Uruguay (50th), Mexico (52nd) and Costa Rica (54th), and as distancing Brazil (75th). In the region, besides Uruguay, only Barbados (37th), Argentina (49th), Chile (44th) and Antigua and Barbuda (47th) rank higher. Moreover, according to the World Wide Fund For Nature's *Living Planet* report of 2006, Cuba is the only country with an acceptable 'ecological footprint' (WWF, 2006, page 19).

Where should Cuba go from here? Special care will need to go into updating and strengthening the technological infrastructure of its R&D institutions. For example, between 2005 and 2008, the Cuban government modernized the local Meteorological Service operated by the Institute of Meteorology by installing modern computing systems and other equipment. In 2009, this was still work in progress but there were already signs of a marked improvement in the efficiency of the early warning and hurricane-tracking systems. This modernization process should extend progressively to other branches of meteorological science like the mathematical modelling of potentially dangerous natural events. In the near future, it will be imperative to update the research technology of centres involved in other absolute priorities for R&D, such as food security or energy research.

Some strategic areas have been proposed as priorities for the short and medium term, to drive renewed investment in S&T infrastructure, which will of course be dependent on the country's possibilities for funding. These areas have been identified by means of a detailed consultation process conducted in 2007–2008 by CITMA, in which the Academy of Sciences took part. The process received input from more than 600 scientific experts, university professors and decision-makers, and includes contributions from territorial authorities and business leaders. The identified strategic areas can be summarized as follows:

- Innovation conducive to import substitution, a higher standard of living and more efficient production processes, such as in the areas of food production, construction technologies, water management, energy-efficient technologies and renewable sources of energy. By 2020, it is hoped that 18% of the country's total energy consumption will be provided by renewable sources.

- Competitive opportunities to attain a level of excellence in areas where Cuba has recognized capacities, or is developing such capacities, in order to enhance exports and improve living conditions: primarily, selected areas of biotechnologies, ICTs and advanced medical equipment; this includes the expansion of specialized value-added S&T services, as in the case of medicine.

- S&T fields in which Cuba must reach the forefront of knowledge or keep up with relevant new and convergent developments, such as materials science, bioinformatics and neurosciences. With regard to nanoscience and nanotechnology, a government endeavour is currently devoted to capacity-building, with special emphasis on training highly qualified human resources to work in the field.

- S&T problems that are especially relevant to Cuba's sustainable socio-economic development and to which significant contributions can be provided by the national STI system. Efforts in this area mainly focus on devising science-based measures to adapt to the impact of climate change, as well as applied research related to reducing vulnerability to natural disasters.

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Cuban National Statistical Office: www.one.cu

Ismael Clark Arxer was born in Havana in 1944. After graduating as a medical doctor from the University of Havana in 1967, he specialized in clinical biochemistry at the National Centre for Scientific Research. His work there was interrupted in 1975 when he took up a one-year fellowship at Friedrich-Schiller University in Germany.

Dr Clark Arxer has been linked to the Cuban Academy of Sciences since 1977, acting successively as General Scientific Secretary, Vice-President for Biology and Medicine, and as the Academy's First Vice-President. Following the creation of the Ministry for Science, Technology and Environment in 1994, he was appointed First Vice-Minister. Two years later, he was made President of the Cuban Academy of Sciences at the time of its reorganization.

He was the elected Chairman of the Caribbean Association of States' Special Committee for Co-operation in Education, Science and Technology, Health and Culture from 1996 to 1998, and he served from 2000 until 2005 as Secretary of the Caribbean Scientific Union.

Dr Clark Arxer is Full Professor at the University of Havana and at the Higher Institute of Technology and Applied Sciences (inSTEC). He is a member of both the Caribbean Academy of Sciences and of the Academy of Sciences of the Dominican Republic. Many of his articles have been published in Cuban journals and in specialized volumes in Mexico, Spain, Trinidad and Tobago and Venezuela.