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Evaluating patterns of national and international collaboration in Cuban science
using bibliometric tools

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**Evaluating patterns of national and international
collaboration in Cuban Science using bibliometric tools**

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Keywords:	Building scientific capacity, Cuba, Scientific collaboration, Author Affiliation, Science policy, Bibliometric

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Abstract

Purpose - The study was designed to explore the hypothesis that collaboration was a key characteristic of Cuban science to maintain their scientific capacity during a period of economic restrictions and an important feature of Cuban science policy and practice for the benefit of society.

Design/methodology/approach – Collaboration was studied through Cuban scientific publications listed in PubMed for the period 1990 to 2010. The search was carried out using the advanced search engine of PubMed indicating <Cuba> in the affiliation field. To identify participating institutions a second search was performed to find the affiliations of all authors per article through the link to the electronic journal. A dataset was created to identify institutional publication patterns for the surveyed period. Institutions were classified in three categories according to their scientific production as Central, Middle or Distal: the pattern of collaboration between these categories was analyzed.

Findings - Results indicate that collaboration between scientifically advanced institutions (Central) and a wide range of national institutions is a consequence of the social character of science in Cuba in which cooperation prevails. Although this finding comes from a limited field of biomedical science it is likely to reflect Cuban science policy in general.

Originality/value – Using bibliometric tools the study suggests that Cuban science policy and practice ensure the application of science for social needs by harnessing human resources through national and international collaboration, building in this way stronger scientific capacity.

Keywords Author Affiliation, Bibliometric, Building scientific capacity, Cuba, Scientific collaboration, Science policy

Paper type Research paper

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Introduction

International organizations and scholars have recognized Cuban scientific achievements even in those days when the country faced economic difficulties (Daar et al., 2002; López-Mola et al., 2006; De Vos et al, 2006), by pointing out strengths in the Cuban science and technology system. This article explores the patterns of Cuban scientific collaboration, whether or not it is an indication of the scientific capacity of the country supporting those achievements related to the health of the Cuban population.

Assessing scientific performance of a particular country implies the measurement of their scientific output, mainly through standard indicators used internationally to evaluate comparatively the science and technology performance of countries, nations or regions. However, the interest is to investigate if there is any distinctive patterns in Cuban scientific collaboration emerging from two characteristics that have been attributed to the culture and ethos of the Cuban scientific community when pursuing their aims: first, conducting their research through cooperation among institutions with different resources and expertise and second concentrating their effort on those topics affecting the Cuban population. Clark Arxer referred to these two features of the Cuban scientific community in the chapter about science in *Cuba* published in the *UNESCO Science Report 2010: The current status of Science around the World* (Clark-Arxer, 2011, 127) when explaining the case of Cuban biotechnology as the typical approach of the country's effort in research and development. Moreover, Clark-Arxer explained "national collaboration replaces competition among individuals as a driven force of Cuban biotechnology". This statement is explored through the study of the patterns of collaboration in Cuban scientific publications. Other features mentioned in this report included: the government as a source of investment, the implementation of a close linkage between research and commercialization, the generation of spin off state enterprises coming from scientific institutions and the harnessing of scientific effort for products that can reach foreign markets especially in the developed world (López-Mola et al., 2006).

Perhaps one of the first theories of scientific collaboration was developed by Donald Beaver and Richard Rosen in 1978 (Beaver and Rosen, 1978). Defining scientific collaboration as the collaborative scientific research acknowledged by co-authorships, Beaver and Rosen concluded that collaboration emerged as a result of the professionalism of science, first observed in France in the middle of the eighteenth century, and also found in other countries as the result of financial support for scientific activities (Beaver and Rosen, 1979). In this study, the author's

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3 affiliation was not considered when analysing collaborative scientific articles; the focus
4 remained in demonstrating the origin of collaboration and the increasing number of co-authors,
5 and the appearance of teamwork as a mode, later associated to the beginning of the “Big
6 Science” (Price 1963, 90).
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10 Some factors influencing this growth of scientific collaboration have been attributed to the
11 interdisciplinary nature of breakthroughs in science and the increase in the connectivity between
12 scientists all over the world by the revolution in digital communication and the access to the
13 Internet (Stephan, 2012, 75), as well as the need of teamwork to overcome the degree of
14 specialisation driven by the growth of knowledge (Price, 1963, 83). In a study examining trends
15 in collaboration between 662 major U.S. universities Benjamin Jones and collaborators (2008)
16 found that collaboration measured as co-authorship between universities was steadily increasing
17 from the practically non-existent in 1975 to more than 30% of the publications in science,
18 engineering and social sciences in 2005. The authors also found that collaboration between
19 universities has a citation-impact advantage over collaboration within universities. Earlier in
20 1990, Narin and Whitlow found higher rates of citation of internationally collaborative papers
21 compared to the rest of publications in a study of European scientific publications (Narin and
22 Whitlow, 1990)
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33 Evidence of how international collaboration in science emerged and developed came from
34 studies analysing scientific publications dominated by advanced nations or those economies in
35 transition with significant production of scientific articles (Luukkonen et al, 1992; Glänzel
36 2001). However, those studies have been relevant in establishing methodologically the way to
37 evaluate this trend of increasing collaboration between nations.
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43 An insightful approach linking international collaboration with the process of building scientific
44 capacity in less developed nations was carried out by the team led by Caroline Wagner at RAND
45 (2001). In this comprehensive report, which includes a study of 150 countries, the authors
46 created an index of science and technology (S&T) capacity for classifying those countries
47 according to their development in S&T. They also looked at whether collaboration between
48 researchers from developed and developing countries might contribute to the process of building
49 scientific capacity in those nations less developed.
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55 It is therefore worthwhile exploring if any particular characteristic of the national and
56 international collaboration of Cuban institutions might play a distinctive role in national
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3 development. To study the national and international collaboration of Cuban institutions we are
4 selected the field of biomedical sciences because improving the health of the population has been
5 a priority of the Cuban government since 1959 (Marimón-Torres and Martínez-Cruz 2010). This
6 might explain why Cuba has health indicators typical of developed countries (Keck and Reed,
7 2012). Perhaps one of the most successful examples of developing science to support a high
8 standard of public health is the case of immunology (Lage, 2012). Additionally biotechnology in
9 Cuba followed a particular path for development, which embodied the social character of Cuban
10 science (Reid-Simon, 2010, 168; Feinsilver, 1993, 122), delivering successful results to
11 contribute to the country's economy (Pérez-Ones and Nuñez-Jover, 2009; Lage-Dávila, 2013,
12 145).

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15 Cuban scientific output and collaboration have been systematically studied by bibliometrists
16 (Araujo-Ruiz et al, 2005; Vega-Almeida et al 2007; Arencibia-Jorge and Moya-Anegón, 2010;
17 Arencibia-Jorge et al, 2013 and Zacca-González et al, 2015) and their work has contributed to
18 identify achievements and problems in the process of improving the scientific communication in
19 the national system of scientific and technological innovation. Building on their contributions,
20 the present work intends to address the leading role of more advanced institutions in a process of
21 extending the scientific capacity of the country in a period of economic restrictions.

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24 Although the number of scientific articles is a strong indicator measuring the effort of any
25 particular country in the race to develop their capacities, there are other factors deciding the
26 effectiveness of the inputs in developing S&T, among them, the technological infrastructure and
27 the adequate or optimal institutional coordination and cooperation (for more information about
28 constructing an index for measuring scientific capacity see Wagner (2008, 121).

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31 This exploratory study will look at evidence coming from Cuban scientific publications using
32 bibliometric tools. Accepting the limitations this study might have, it should support further
33 research into the role of scientific collaboration in Cuba and how it might be enabling the
34 scientific capacity of the country for development.

35 36 37 **Design/methodology/approach**

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40 There are advantages and disadvantages in choosing the appropriate database to access the
41 information on scientific publications. PubMed as a free online database allowed us to carry out
42 this exploratory study focussing on medicine and biomedical research. PubMed [1] was launched
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3 on the Internet by the National Library of Medicine in the United States in 1997. It currently
4 comprises more than 24 million documents from more than 5,600 source journals in biomedical
5 literature from MEDLINE and life sciences journals. It was one of the databases used to study
6 the national health research priorities of Latin America and the Caribbean in addition to LILACS
7 (Revez et al., 2013) suggesting its validity to study publications in health research in the region.
8 One limitation of PubMed compared to Web of Knowledge (WoK) or Scopus is that this
9 database did not show until 2014 all authors' affiliations, but only the address of the institution
10 signing off the scientific paper. However, this feature can work to our advantage because the set
11 of publications retrieved under author affiliation <Cuba> will be those publications in which
12 Cuban institutions play a leading role. On the other hand, PubMed links to the electronic
13 publications of peer reviewed journals allowed us to find and complete all author affiliations. We
14 also considered the possibility of using the Cuban database called CubaCiencias held by the
15 Scientific and Technological Information of the Republic of Cuba, but this database seems to
16 require a better standardization in the field of author's affiliation, which is an essential part of
17 our study (Araujo Ruiz et al, 2005). Another Cuban bibliographic database is Biblioteca Virtual
18 en Salud (BVS) from the National Centre of Information in Medical Sciences (Infomed)
19 including sources of information from Cumed, Ibecs, LILACS, MEDLINE, PubMed and Recu.
20 However at the time we conducted this investigation, the search engine of BVS from Infomed
21 did not include author affiliations in the available fields, not even in the advanced search, neither
22 from Virtual Health Library (VHL), Bireme, Office of Pan-American Health Organization.
23 Therefore PubMed is the most convenient database source for the purpose of this study at this
24 stage. It may not give the best representative outputs to study the model of Cuban scientific
25 collaboration, but will allow us to process enough information to have the preliminary view
26 examining the role of Cuban scientific collaboration in the process of building national capacity,
27 as well as identifying pitfalls for further studies. The implication of studying this selected sample
28 means that the pattern of collaboration (or absence of it) has been decided by Cuban
29 researchers/institutions, as well as the topics of the research involved.
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49 *Search strategy and normalization process*

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52 PubMed provides an *Advanced Search* for specific fields and we chose *Affiliation* with the word
53 <Cuba>, limiting the field of *Publication dates* to the years <1990>, <1995>, <2000>, <2005> and
54 <2010>. Each set of Cuban documents per year was downloaded in an *ad hoc* dataset called
55 *SciPubCuba*. PubMed also provides the direct link to the original document in the cases of
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3 electronic journals and therefore through that link a second search was carried out to obtain the
4 affiliations of all authors. Some references were linked to the Latin American repository library
5 online (Scientific electronic library online, ScieLO, Brazil) from which all authors' affiliations
6 were also taken using ScieLO access to original document. This second search provided
7 additional information, specifically institution names, to complete the field of all author
8 affiliation in our *SciPubCuba* dataset. The percentages per year of documents in PubMed linked
9 to the electronic journal (eJ-PubM) were: 1990 (2.3%); 1995 (5.4%); 2000 (62.3%); 2005
10 (79.3%) and 2010 (80.4%).
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18 Institution names were disambiguated from alternative English translations of the same name
19 helped by author knowledge of those places in question and by searching in the Internet about
20 their location and function. In some cases, electronic e-mails to the corresponding author were
21 sent to confirm the name and location of the affiliations. Disambiguation of different names or
22 acronyms in Spanish was also performed as well as a manual inspection to eliminate false
23 documents.
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28 The normalization of the qualitative evaluation of the content of the Cuban scientific production
29 was carried out by individual and manual inspection of the content of the publication (only eJ-
30 PubM) classifying them by disciplines and type of health subjects.
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35 Disciplines and health subjects were classified by integrating the content of title of the
36 publication, departments involved in the affiliation and the journal title. For instance: in the
37 article "*Clonal distribution of disease-associated and healthy carrier isolates of Neisseria*
38 *meningitidis between 1983 and 2005 in Cuba*" the discipline was classified as "MOLECULAR
39 BIOLOGY" according to the main department involved: "*Department of Molecular Biology,*
40 *Division of Biotechnology, Finlay Institute*". For the health subjects we classified this publication
41 as "CERTAIN INFECTIOUS and PARASITIC DISEASES (I)" according to the content of the
42 title and the scientific journal in which it was published: "Journal of Clinical Microbiology".
43 Health subjects were classified according to the International Classification of Diseases (IDC-
44 10th, WHO, 2015) and related health problems, which is commonly used to provide uniform
45 views of the health situation of countries and populations. Some disciplines and health subjects
46 were grouped because they often are closely related (shown in figures 7 and 8). When more
47 distant disciplines and health subjects were parts of the research published, they were considered
48 MULTIDISCIPLINARY. Articles in applied research addressing explicitly a disease were
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3 counted for the mentioned health problem even if the contribution came from institutions of non-
4 medical research or services.
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7 The retrieval of scientific articles from PubMed was concluded in December 2013. Due to the
8 small PubMed coverage of electronic journals for 1990 and 1995, those years were excluded in
9 this study.
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12 13 14 15 16 *Datasets SciPubCuba and CubanInstitutions*

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19 *SciPubCuba* was our reference dataset in which each document corresponding to a scientific
20 article received an identification reference number (IRN) for each studied year. The PubMed
21 reference number was also kept as a second alternative identification. *CubanInstitutions* was our
22 working dataset created in Excel with the names of Cuban institutions as their names were
23 appearing in the search. A record of Cuban institutions and their IRN per publication per year
24 was created to count and classify their articles according to the nature of their collaboration.
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30 *SciPubCuba* outputs are net publications ascribed to only one institution with a unique IRN and
31 PubMed number. Thus, total net publications (TNP) was the aggregate number of publications
32 for the years 2000, 2005 and 2010 and it was obtained from this reference dataset, therefore
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$$37 \text{TNP} = \sum (\text{IRN}_i)_{2000} + \sum (\text{IRN}_j)_{2005} + \sum (\text{IRN}_k)_{2010}$$
$$38$$

39 In this case *i*, *j* and *k* are unique articles in 2000, 2005 and 2010 respectively.
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43 *CubanInstitutions* was our working dataset created with the list of Cuban institutions (column)
44 and their articles (IRNs per row) per year (sheets). Articles per institution were then classified in
45 four types: only one institution (N), more that one national institution (NN), only one national
46 institution with one or more international collaboration (NI) and more than one national
47 institution with one or more international collaboration (NNI).
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52 Institutional publications (IP) accounted for all articles in which the institution participated
53 regardless of the position of the author affiliation and is obtained by counting their IRNs (integer
54 counting) per institution and year. The total institutional publications (TIP) were obtained by
55 adding the IPs of all institutions in aggregate for the years 2000, 2005 and 2010. Therefore,
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$$TIP = \sum (IP_i)_{2000} + \sum (IP_j)_{2005} + \sum (IP_k)_{2010}$$

In this case i, j and k = institutional publications in 2000, 2005 and 2010 respectively

A diagram of the experimental design used in this study is shown if figure 1.

Defining institutions according to their publication outputs and functions

For the purpose of this study, which focused on biomedical science, publications of the Cuban institutions were classified according to the number of their IPs in the aggregated years regardless of the status or tiers of the institution in the National Science and Technology System. The top 20 more productive institutions were called Central group; those institutions with less than 5 institutional publications were called Distal group including 156 out of 201 Cuban institutions; and those in between these two groups including 25 institutions were called Middle group. Although it is an arbitrary division, it allows us to create a setting in which more active researchers working in top institutions (Central) publish with transient collaborators in geographically dispersed institutions (Distal), typical behaviour in scientific communication first described in the study of the Information Exchange Group 1 (IEG 1) on Oxidative Phosphorylation and Electron Transport Chain (Price and Beaver, 1966). Other scatter or skew distributions have been described for journals, known as Bradford's Law, or for author productivity known as Lokta's Law (Sen, 2010). However we are not aiming to prove if Cuban scientific publications in biomedical sciences follow or not any particular distribution. We are interested to study the relationship between contributing institutions with different resources and expertise through their national and international collaboration and how it might strengthen Cuban national scientific capacity.

The institutions were also classified according to their principal role such as higher education, research and development, services and production, etc. In the majority of cases the name of the institution indicates their function as universities (and polytechnics) and were considered higher education (HE) and Science & Technology (S&T). In the case of medicine, Cuba has national institutes of different specialties such as Institute of Cardiology and Cardiovascular Surgery (in Spanish as ICCC), classified as research institutes-Hospitals; other research institutions (R&D) in the Ministry of Health were not hospitals such as Centre for Research and Development of Medicaments (in Spanish as CIDEM); Teaching hospitals (TH) were separated from general hospitals (GH) and specialized hospitals (SH) such as maternity hospitals, which are mainly

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3 service (S). Other national, provincial or municipal institutions were also classified as centres
4 aiming to improve the public health such as the National Centre for Quality Control of
5 Medicaments (CECMED), or Provincial Centre of Hygiene and Epidemiology of Santiago de
6 Cuba, or Municipal Unit for Surveillance and Control against Vectors in Cumanayagua,
7 Cienfuegos. Although classification of all institutions might look too specific, we decided to
8 keep details showing the geographic distribution of them especially in the Distal group.
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14 Once the three groups of institutions were established the nature of national and international
15 collaboration between Central institutions with the other two groups was explored through
16 graphic representation of the multivariate data available in Excel. Data was prepared in two
17 spreadsheets of collaborative IPs per institution of the Central group for the analysis of the
18 national and international collaboration. For both sets of data IPs showing collaboration within
19 Central and with Middle and Distal were counted and each institution received equal recognition
20 regardless of the position of the author affiliation, but counted only once in the case of more than
21 one author per institution.
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28 Other sources used supporting the analysis of scientific outputs in the context of Latin American
29 and the Caribbean were: Science Citation Index (SCI), Thomson and Reuters and SCImago
30 journals and country rank (SJ&CR), powered by Scopus database, Elsevier as well as Science
31 and Engineering indicators (NSF 2000 and 2014) from National Science Foundation, United
32 States of America. Additionally we used the World Bank data for normalizing the number of
33 publications per inhabitants of the countries of interest available at The World Bank website [3].
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40 **Results**

41 *Cuban scientific outputs retrieved from PubMed*

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44 Scientific output of Cuban institutions measured by the number of publications retrieved from
45 the PubMed database using advanced search is shown in Table 1. The number of total net
46 publications (TNP) in aggregate for the year 2000, 2005 and 2010 was 861 from which 646 were
47 further completed in the field of all authors affiliation using the electronic Journals linked to
48 PubMed (eJ-PubM), representing 75% of the all articles in the aggregated years. Cuban
49 collaborative articles represented 60.2% of those articles that were further completed with all
50 author affiliations.
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57 *Pattern of collaboration measured through Cuban institutional publications*

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3 All Cuban institutions shown in the author affiliations of the eJ-PubM sample were listed with
4 their publications classified as N (only one Cuban institution) and NN (more than one Cuban
5 institution), NI (one Cuban institution and one or more international institutions) and NNI (more
6 than one Cuban institution and one or more international institutions) for the years 2000, 2005
7 and 2010.

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11 The total aggregate number of institutional publications (TIP) was used to classify the groups in
12 Central, Middle and Distal as described under methods. Table 2 shows the distribution of Cuban
13 institutions according to their output in scientific publications and their main function.
14 Institutions in the Central group represented 10% and Middle and Distal groups 12.4% and
15 77.6% of all institutions respectively. Among the two hundred and one institutions listed 23.5%
16 belong to Higher Education, 25.5% are institutions of Research and Development, 15.5% are
17 Research and Services/Production and 35.5% are institutions either supporting the National
18 Health System or dedicated to production or services. All institutions in both Central and Middle
19 groups are all involved in research while in the Distal group it is only 54%.

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21 [Appendices 1 (Central group), 2 (Middle group) and 3 (Distal group): Cuban institutions (201)
22 listed from the author affiliations found in the articles of electronic journals linked to the
23 publication records in PubMed.]
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27 The total net scientific papers (TNP) in aggregate for the three years were 646 articles from eJ-
28 PubM. However, when counting them as institutional publications the total number of scientific
29 papers reached 980 articles (TIP) indicating the degree of participation of more than one
30 institution per scientific article.
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34 Collaborative papers including national and international institutions represented 60% of the 646
35 net publications (Table 3). The Central group as expected (Price and Beaver, 1966) representing
36 10% of all institutions generated 497 articles accounting for 76.9% of the total net publications
37 while the Distal group of 156 institutions contributed with 10.4% to the net publications. The
38 proportion of collaborative articles including the participation of national and international
39 institutions were 58.8%, 69.5% and 59.7% for Central (C), Middle (M) and Distal (D) groups
40 respectively related to total net publications (TNP) per group (sub-TNP). However, the
41 collaborative net publications are concentrated in the Core group and represents 45.2% (292
42 articles out of 646), while M and D only contribute with 8.8% (57 out of 646) and 6.2% (40 out
43 of 646). Obviously these values do not fairly represent the real contribution of institutions in M
44 and D groups to the collaborative scientific output of Cuban institutions since as net publications,
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articles are attributed only to the first author affiliation.

Institutional publications (IP) allow analysis of the pattern of collaboration and the relationship among national institutions in which all participating institutions were accounted for their contributions to the article regardless of the position of the institution in the list of contributing authors. Collaborative articles both involving national or international co-authorships and counted by IPs represented 74% of 980 IPs. Articles with more than one Cuban institution (NNs) either national or international represented 75% of collaborative papers (only NI excluded from collaborative papers) indicating the strong relationship among Cuban institutions (Table 3), with the Central group leading the cooperation (38.9%), followed by the Distal group with 22.3%.

National Collaboration

The Central group provides the focus for the analysis of the pattern of collaboration through the relationship of their collaborative papers with the institutions within the Central (C) group and with the Middle (M) and Distal (D) groups using IPs as a source of data. In general there is a linear relationship ($y = 2.2x$ and $R^2 = 0.899$) between the amount of collaborative papers within the C group (NN-C) and the total number of national collaborative papers (Figure 2A), accounting for 50% of national collaboration. The top five institutions by the volume of their publications contribute more to the collaboration within the Central group, as they are part of the Scientific Park in West Havana. Those institutions with a higher volume of publications (larger diameter of the circles) are the Institute of Tropical Medicine Pedro Kourí (IPK) with 141 papers, the Centre of Genetic Engineering and Biotechnology (CIGB) with 130, University of Havana (UH) with 104, National Centre of Scientific Research (CNIC) with 59, University of Villa Clara (UCLV) with 36 and the Centre of Molecular Immunology (CIM) with 34. The next institutions of the Central group which fit less to the linear relationship of NN *versus* NN-C are the National Institute of Neurology and Neurosurgery (INN), Hospital “Hermanos Amejeiras (HHA), Centre of Pharmaceutical Chemistry (CQF), Cuban Neuroscience Centre (CNC), National Institute of Oncology and Radiology (INOR), Higher Institute of Medical Sciences of Havana (ISCM-H) and Institute of Nephrology “Abelardo Buch” (IN-AB). The last sub-group of institutions in the Central group with the lowest contribution in terms of national collaborative papers are Central University of Las Villas (UCLV), International Centre for Neurological Restoration (CIREN), Finlay Institute (IF), University of Oriente (UO), Higher Institute of Technologies and Applied Sciences (InSTEC), Centre of Immunoassay (CIE), National Centre of Animal Health (CENSA) and University of Matanzas Camilo Cienfuegos (UM-CC).

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3 The collaboration of the institutions of the C group with the ones of the M and D groups did not
4 follow a linear relationship (Figure 2B). The majority had stronger collaborations with
5 institutions in the D group, as the relation M:D shows for IPK (1:3), HHA (1:2), UO (0:4), CQF
6 (1:3), CENSA (0:3) and IN-AB (4:9). Leading the institutions with stronger collaborations with
7 those of the M group are the CNIC (12:5) and ISCM-H (3:1). The rest of the institutions
8 collaborated almost equally with institutions in M and D groups. Interestingly, the strong
9 collaboration of CNIC with M group might indicate the role of this institution as incubator of
10 spin-off institutions (either research or state enterprises) with a defined profile of applied
11 science.
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19 *International collaboration*

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21 International collaboration of Cuban institutions has been increasing steadily since 2000 with
22 European institutions sharing the highest presence in collaborative papers with Cuban
23 institutions (Figure 3). Fourteen European countries have co-authored 249 articles with Cuban
24 institutions when looking at the aggregate data of institutional publications; and in 2010 the
25 European countries with more collaborative papers with Cuba were Spain (46; 36.2%), Belgium
26 (17; 13.4%), Germany (16; 12.6%) and United Kingdom (14; 11%) out of 127 collaborative IP.
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28 Nine Latin America countries participated in collaborative papers in the period of study
29 accounting for 100 IPs and in 2010 the Latin American countries with the highest share were
30 Brazil (25; 39.7%), Argentina (15; 23.8%) and Mexico (10; 15.9%) out of 63 collaborative IPs.
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32 Japan is the individual country with highest share per region with 44% of collaborative papers in
33 2010. For North America, in spite of being the region of highest output in science, the share of
34 collaborative papers with Cuban institutions has been relatively lower with only 35 collaborative
35 IPs; and in 2010 both Canada (6; 46%) and United States (7; 54%) were similarly represented for
36 a total of 13 articles. In 2010 all regions except Africa were publishing in collaboration with
37 Cuban institutions. International organizations such as WHO, UNESCO and PAHO have been
38 represented through their experts co-authoring papers with Cuban institutions with 2 and 6
39 publications in 2000 and 2010 respectively. For the years included in this study, countries
40 publishing with Cuban institutions were: Argentina, Brazil, Chile, Colombia, Mexico,
41 Nicaragua, Paraguay, Peru, Puerto Rico, Canada, United States, Austria, Belgium, Finland,
42 France, Germany, Italy, Portugal, Spain, Sweden, Switzerland, United Kingdom, Russia,
43 Bangladesh, Cambodia, China, Iran, India, Japan, Korea, Malaya, Philippines, Singapore, Syria,
44 Thailand, Vietnam, Uzbekistan, Australia and New Zealand.
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3 Collaborative papers with international institutions represented 41% of the total net publications
4 (266 out of 646). When analysing the contribution of each group of institutions to the total IPs in
5 terms of publications with at least one international institution (NI+NNI), all institutions in the C
6 group co-authored 261 papers (69%); 24 out of 25 institutions of the M group participated in 47
7 papers (12.4%) and only 51 out of 155 institutions of the D group contributed participating in 70
8 papers (18.5%) for a total of 378 IPs involving international collaboration (Table 3). For
9 institutions in M and D groups national collaboration (NN) is stronger (50% and 53%
10 respectively) versus international (33% and 34% respectively) in relation to their own
11 institutional publications.
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18 The contribution to the total international collaboration of individual institutions in the Central
19 group publishing with one or more international institutions (NI) was 80.4% (for NI: 144 out of
20 179 IPs) and 58.8% (for NNI: 117 out of 199 IPs) when other Cuban institutions were
21 participating in the collaborative articles (see Table 3). The leading role of the Central group
22 incorporating institutions in M and D groups is shown in Figure 4, with the Institute of Tropical
23 Medicine Pedro Kourí (IPK) sharing almost 80% with D institutions in those articles including
24 another Cuban institution. Another eleven institutions of the Central group share a third or more
25 of their international collaboration with institutions of the Distal group.
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32 33 *Evolution and content of the Cuban scientific collaboration*

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36 International collaboration between scientific institutions co-authoring articles in science and
37 engineering (S&E) is another important feature strengthening the countries capabilities in
38 scientific research and development. International co-authored articles in S&E have increased by
39 133% from 90,867 articles in 1997 to 211,841 in 2012 and United States remains the strongest
40 hub for scientific collaboration in the world stage (NSF 2000 and 2014).
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46 After the collapse of Soviet Union and socialist countries of Eastern Europe at the beginning of
47 1990, Cuba evolved her pattern of international collaboration probably as a way to maintain the
48 commitment for the development of science initiated since the early 1960s. Figure 5, generated
49 from data of the National Science Foundation, Science and Engineering indicators (NSF 2000),
50 shows how different is the pattern of Cuban international collaboration from other countries of
51 the region. Latin American countries as shown in the figure 5, shared 32%- 55% of their
52 internationally co-authored articles with the U.S. in the period before and after 1990, while Cuba
53 showed a distinctive turn in the pattern in which the collaboration with Soviet Union was
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3 replaced by Spain. Diversification of the international collaboration was also characteristic of
4 this period by producing collaborative articles with countries such as Canada, Belgium,
5 Denmark, Japan and Austria, as well as increasing the share of scientific collaborative articles
6 with others such as the United Kingdom, Switzerland and France (NSF 2000). Even with the
7 United States, Cuba experienced an increase in scientific collaboration regardless of the
8 geopolitical distance between both countries.
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14 At the beginning of this century Cuban scientific output measured by the number of articles
15 published in international journals has been shown to be not far from the mean of the Latin
16 American and the Caribbean (LAC) scientific articles when normalized by population (Clark-
17 Arxer, 2010), being slightly higher in 2001 and lower in the following years up to 2007. In
18 general, for some countries, the evaluation of scientific output changes depending on the sources
19 used to obtain the science and technology indicators, as two different results might arise by
20 counting scientific articles either from Science Citation Index (SCI), Thomson and Reuters or
21 from SCImago journals and country rank (SJ&CR), powered by Scopus database. Latin
22 American countries are better represented in Scopus than in SCI (Science Citation Index) and
23 Cuba ranks in fifth (NSF, Figure 6) or fourth (SJ&CR, Figure 6) positions in the amount of
24 scientific and engineering (S&E) articles for the region accounted by S&E articles per million of
25 population. Using SJ&CR [2] we found that more than a third of total publication in these top
26 seven countries of the LAC correspond to international collaboration for the period 2000-2010
27 with Chile, the leading country in the table, having 52.5% of international collaboration,
28 followed by Colombia (52.1%), Cuba (44.9%), Venezuela (43.5%), Mexico (40.2%), Argentina
29 (40.5%) and Brazil (27.8%).
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43 In our study limited to a cross section of aggregated publications for the years 2000, 2005 and
44 2010 in which all author affiliations were recorded, we found as expected, that the disciplines
45 contributing more to overall publications were immunology and microbiology (19.7%), the
46 group of biochemistry- molecular biology - biotechnology (18.6%), medicine (15.6%) and the
47 group of pharmacology- toxicology –pharmaceuticals (15.2%); interestingly the group of
48 chemical sciences (16.1%) had strong representation, which denotes its role supporting
49 biomedical research in structural and molecular biology (figure 7). This result is an expression of
50 national policies to advance science to improve the health of the Cuban population and to
51 stimulate innovation in areas that can reach foreign market such as biotechnology. Immunology
52 and microbiology are essential disciplines in the diagnosis, cure and prevention of transmittable
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3 diseases, including the development of new vaccines. Immunology is also a key discipline in
4 Cuban approach to develop technologies of immunotherapy in the treatment of cancer. The
5 groups with less collaborative articles are immunology-microbiology and medicine with 46%
6 and 48% respectively compared to the total of 60%. The case of immunology-microbiology
7 seems to be a consequence of the high representation of articles related with infectious diseases
8 in PubMed since Revista Cubana de Medicina Tropical is the only Cuban journal indexed in this
9 database. Indirectly it might suggest that disciplines other than immunology and microbiology
10 only have a selected representation in PubMed, in which collaborative articles are strong
11 candidates to be accepted in foreign journals. In the case of medicine the observed low
12 collaboration has been attributed to the degree of specialisation of the National Institutes of
13 Health (Vega-Almeida, 2007) and publications by departments in hospitals concerning their own
14 findings and report of cases. Low collaboration in the health sector has been also shown in other
15 studies (Arencibia Jorge et al., 2013, Zacca González et al., 2015) and might be the reason why
16 the output in the sector is less than the expected.

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18 Not surprisingly, the classification of the articles by diseases and health disorders showed the
19 same trend with more representation of scientific contribution in infectious diseases (46%),
20 cancer (13%) and disorders of the nervous system (16%) as shown in Figure 8. However, in
21 general articles contributing explicitly to a particular disease or disorder account for 309
22 publications meaning that 62% of this output came from institutions that do not belong to the
23 health sector, but their applied research addressed priorities of the national health system and
24 consequently the proportion of scientific collaboration rose to 69%.

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The case of “dengue” an endemic tropical disease affecting the Cuban population illustrates the
priority given by the government to support research for public good. Research in this topic
attracts only by 0.1% of the total publications in Medline (3,456 out of 3,460,987). However
because of the frequent outbreaks of this infectious disease, research in dengue has been a
priority in the Cuba National Research Programme explaining why Cuba reaches the fourth in
the ranking of national interest among 79 countries with 4.6% of its total publications in this
field and sharing 1.94% of international publications in dengue for the 14th ranking (values
calculated on 20th June 2014 from the available search engine in Medline/PubMed developed by
Corlan, 2012).

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3 Biomedical and biosciences research are generally supported by multiple disciplinary teams and
4 it is sometimes difficult to separate the boundaries between them, however in many cases, one
5 discipline takes the centre of the contribution (Vega-Almeida, 2007).
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9 10 **Discussion**

11 Developing countries have been in constant challenge adapting their resources to improve their
12 capacities to compete on the world stage for the benefit of their societies. With the advent of the
13 knowledge society, the economic growth and social welfare of a country will depend more on
14 the degree of development of its science, technology and innovation system. Although
15 harnessing science and technology resources in these countries depends on several factors,
16 scientific collaboration, both national and international, surely will strengthen their national
17 scientific capacities.
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19 In this study of analysing national and international collaboration of Cuban institutions we
20 explored how to evaluate two characteristics of Cuban science and the possible implications in
21 passing on the benefit of scientific research to Cuban society, while improving the national
22 scientific capacity. It seems that these two characteristics of conducting their research through
23 cooperation among institutions with different resources and expertise and secondly concentrating
24 their effort on those topics affecting the Cuban population helped not only to strengthen the
25 collaboration among top Cuban institutions, but to take science to a broader set of institutions not
26 necessary involved in S&T. Nuñez-Jover and López-Cerezo, (2008) explained the makeup of
27 Cuban scientists as it is described in the content of the Code on Professional Ethics of Cuban
28 Scientists, *"While scientists are required to seek the truth and carry out honest and disinterested
29 work to contribute to the advance of science, the main contribution expected from this work is
30 social welfare, to which individual and corporate interests must be subordinated"* And it seems
31 that this combination of ethics and political will was not only ideological, but practically the only
32 way to survive isolation under circumstances of frequent epidemics suffered by the population in
33 which what was called initially the "Biological Front" and later the "Scientific Pole", played a
34 crucial role. Hostility against the will of the nation to defend the social system turned the
35 inefficiency of the early years in which scientific results did not necessarily translate to
36 innovation, into a network of institutions, strategies and policy aiming to maintain the health of
37 the population and the creation of new sources of export, based on knowledge and innovation.
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3 The strategy of choosing PubMed in order to have those publications related to Biomedical and
4 life sciences might also help to access the best Cuban scientific publications. Cuban institutions
5 might selectively publish in international journals those articles strengthened by collaboration,
6 both national and international. Although the evidence from previous years (1989 to 1994)
7 indicated that Cuban scientists increased their publications in international journals by 211%,
8 while decreasing by 60% the amount of publications in Cuban journals due to a lack of resources
9 in the Cuban publishing sector (Araujo et al., 2005).
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16 We found that 30% of net publications involved more than one Cuban institution (data not
17 shown), and is similar to that found for the multi-university collaboration among US schools in
18 Science and Engineering (Jones et al., 2008) with 32.8% in 2005, which might indicate that
19 Cuban institutions follow the international trend rather than a particular pattern to overcome the
20 economic restrictions during the period post 1990. In another study using co-authorship
21 bibliometric analysis to evaluate collaboration in countries of Latin American and the Caribbean
22 (period 1995-2002), the authors found that the overall collaborative publications represented
23 65% of the total (Sancho et al., 2006). Moreover, the authors found that national and
24 international collaboration of the region represented 26.4% and 35.5% respectively, with a very
25 limited regional collaboration (2.7%) with the exception of Cuba with 26%. In this study the
26 authors used the SCI database and recognized that the representation of Latin American journals
27 is still very low representing only 0.6% of the total. We also found that 40% of net publications
28 of Cuban institutions were with international partners (data not shown) equally following the
29 global trend (The Royal Society, 2011, p 4). As it was pointed out in this report, "*scientists seek*
30 *for excellence in their work by sharing tasks, costs and experience*", and in the case of Cuba,
31 under the circumstances of this period, it might also have a component of outsourcing to ensure
32 access to otherwise limited materials and modern equipment. This also suggests that in addition
33 to the government support for areas of applied research related to population needs, the Cuban
34 researchers actively seek collaboration to advance science in subjects of local interest.
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49 Galvez and collaborators (2000) found that paradoxically developed nations, which accrued
50 more than 85% of world publications, are less inclined to collaborate internationally and at the
51 same time had more transnational publications. International collaboration was 20%, 24%, and
52 39% for North America, Asia and Western Europe respectively, while for Latin America and the
53 Caribbean, Southern Africa, Northern Africa and Eastern Europe was 62%, 59%, 58% and 52%
54 respectively. The reason, they argue, seems to be that developing nations were becoming more
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3 dependent on developed nations, not only economically, but also scientifically. At the same time
4 nations with strong economies naturally tend to develop strong scientific communities (Galvez et
5 al., 2000) among themselves. Although their results seems to support their views, this conclusion
6 came from analysing a relatively short period between 1991 -1998, and using Science Citation
7 Index, which did not evenly cover all regions. While the current study was carried out Zacca and
8 colleagues (2014) showed that collaboration was a key factor behind the development of
9 scientific activities in Latin America in this century. The areas covered in this article were public
10 health and environmental and occupational health and the database used was SCImago Journal
11 and Country Rank. Interestingly they found that Cuba, Colombia and Brazil had the greatest
12 strengths measured by thematic specialization among the countries with most scientific output
13 (Brazil, Mexico, Cuba, Colombia and Argentina).
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22 An unexpected result was the lack of international collaborative articles with Africa as a region,
23 especially when there is a long lasting policy of international cooperation between Cuba and
24 more than 38 countries of the region (Marimón Torres and Martínez Cruz, 2010) in the area of
25 public health. This finding might reflect the difficulties that still prevail in publishing scientific
26 results in some areas of the health sector in which they concentrate more in delivering and
27 reporting the service rather than publishing in scientific journals. This problem also affects the
28 international visibility of Cuban science (Arencibia-Jorge and Moya-Anegón, 2010). It would be
29 interesting to explore why this long-term cooperation with countries in Africa does not
30 correspond to more international scientific publications.
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38 We represented the pattern of Cuban collaboration through the institutional publications and not
39 through the net publications to give equal representation to all participating national institutions.
40 This approach revealed that the Central group is leading the cooperation with almost equal
41 proportion of participation among the three groups. Seventy per cent of Central institutions have
42 articles with institutions in the Distal group. The Institute of Tropical Medicine Pedro Kourí
43 (IPK) showed the highest cooperation with the Distal group with a wider number of institutions
44 often in the same article. Two other institutions by virtue of their policies showed strong
45 collaboration within the Central group and the Distal group: these are University of Havana
46 (UH) (Pérez Ones and Nuñez Jover, 2009) and Centre of Genetic Engineering and
47 Biotechnology (CIGB)(López Mola et al., 2006). This interaction between the Central group and
48 the rest of the institutions seemed to be different to the study of Jones and collaborators, in which
49 they found that the multi-university collaboration is more stratified by in-group university
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3 ranking. However we should stress again the small size of our sample in contrast to 4.2 million
4 articles analysed for a period of three decades (Jones et al., 2008). Our approach focused in the
5 relationship between the most scientifically productive institutions with a wide range of
6 institutions distributed along the country. By taking this approach we centred the attention in the
7 role of leading scientific institutions sharing their resources and experience with less
8 scientifically productive institutions but directly connected either to services or production.
9 Another approach was used describing the production of knowledge and the role of collaboration
10 between different sectors in Cuba by assessing the model of Triple-Helix (Arencibia-Jorge et al,
11 2013), which might fit better for more developed nations. Similarly, when combining
12 bibliometric, socioeconomic and health indicators in the analysis of Latin American output in
13 public health (Chinchilla Rodríguez et al, 2015), the authors could not find that the tangible
14 achievement in health attained by Chile and Cuba were the result of their publishing pattern in
15 the area of public health. Perhaps a combination of those methodologies will lead to better
16 characterise the Cuban scientific performance and its social implications in the science,
17 technology and innovation system of the country. It might be plausible in the future to focus on
18 the rise and evolution of scientific parks and in the role played by older universities fostering
19 scientific research in newly created universities and campuses. Scientific parks embody the
20 essence of the Mode 2 of production of knowledge, described as socially distributed, application
21 orientated, trans-disciplinary and subject to multiple accountability (Nowotny et al, 1996). In the
22 case of Cuba there are other stakeholders within the public sector supporting the process of
23 knowledge production and innovation, such as Youth Technology Brigade (BTJ), with more than
24 200,000 members and the National Association for Innovation and Rationalizations (ANIR) with
25 100,000 members (Nuñez Jover and López Cerezo, 2008).

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The key decision for further studies would be choosing the source of information among all
available databases representing Cuban output in science. Previous studies evaluating the total
scientific production of Latin America and the Caribbean region (Miguel, 2011) found that in
the case of Cuba, 48.6% of Cuban journals (151) listed in LATINDEX were covered by SciELO
(70.5%), RedALyC (37.3%) and Scopus (41.2%) as electronic databases with different platforms
supporting the search and retrieval for bibliometric studies. Moreover, the study of Araujo Ruiz
and collaborators (2005) showed that the Institute Scientific Information Databases (ISI-DBs)
indexed only 20.7% of Cuban articles when compared to the local database CubaCiencias during
the period between 1988 and 2003. In a macro level study of Cuban scientific output combining
socioeconomic and bibliometric indicators, the authors concluded that Scopus was a better

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3 information source when it was compared to WoS (Arencibia-Jorge and Moya-Anegón, 2010).
4 Obviously, studies addressing the visibility of Cuban science in which the databases provide the
5 engine for analysing the citation of articles might still need to use those databases with less than
6 50% representation of Cuban outputs in science. However, when focussing on how Cuban
7 scientific and engineering outputs have contributed to build the scientific capacity of the country
8 and the implication of policies to bring scientific results to society, searching nationally
9 generated databases and documents will provide more information.
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15 *Conclusion and future directions*

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18 In spite of the limitations mentioned above, our results indicate that collaboration between
19 scientifically advanced institutions (Central) and a wide range of national institutions is a
20 consequence of the social character of science in Cuba in which cooperation rather competition
21 prevail (López-Mola et al., 2006). The conclusion comes from a search in the limited field of
22 biomedical science but it might be representative of Cuban science. The Cuban government has
23 supported areas of biomedical research not only to improve the health of the Cuban population
24 but also to strategically create sources of income from high level biotechnology research as well
25 as expanding its capacity to effectively co-operate with developing countries and emerging
26 economies (Sáenz et al., 2010, Keck and Reed, 2012). However, given the economic restrictions
27 of the period of study it seems that the nature of this collaboration was a decisive component for
28 success. Probably extending the search to other fields such as social sciences will allow the study
29 of more features of Cuban collaboration as it could be foreseen from the model of Yaguajay
30 (Lage-Dávila, 2004).
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41 Further studies will also explore the nature of collaboration between Cuban scientists working in
42 the country and those abroad using Scopus as a database. One of the advantages of Scopus is the
43 scientist identification number, which allows the following of the movement of the researcher
44 through different institutions and countries during their working life (Plume, 2012). Migration
45 of highly skilled citizens towards developed countries has been increasing in the last decades
46 (Docquier and Rapoport, 2012) and developing countries are looking for policies to harness the
47 potential lost through the brain drain (Le Bail and Shen, 2008). Indeed, contributions from the
48 outcome of transnational knowledge through diaspora networks have been documented
49 (Guchteneire et al., 2006, Mahroum et al, 2006)
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3 Human capital is the vital asset of Cuban science: highly skilled and trained to perform not
4 always under optimal conditions, they embodied creativity, resilience and perseverance, all
5 essential in a scientist (Stone, 2015). However human capital is mobile and can reach resources
6 anywhere any time; and by the same token a risk of migration might be a threat to the effort of
7 building scientific capacity.
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12 The creativity in overcoming difficult times seems to be part of the idiosyncrasy of Cuban
13 socialism and there are many instances in which cooperation works as leverage to create
14 knowledge and innovation (Núñez Jover, 2010, 135; Lage Dávila, 2013, 145).
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21 Endnotes:
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24 [1] Information updated on 24th September 2014 at <http://www.ncbi.nlm.nih.gov/pubmed> and
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Figure 1. Diagram of the experimental design

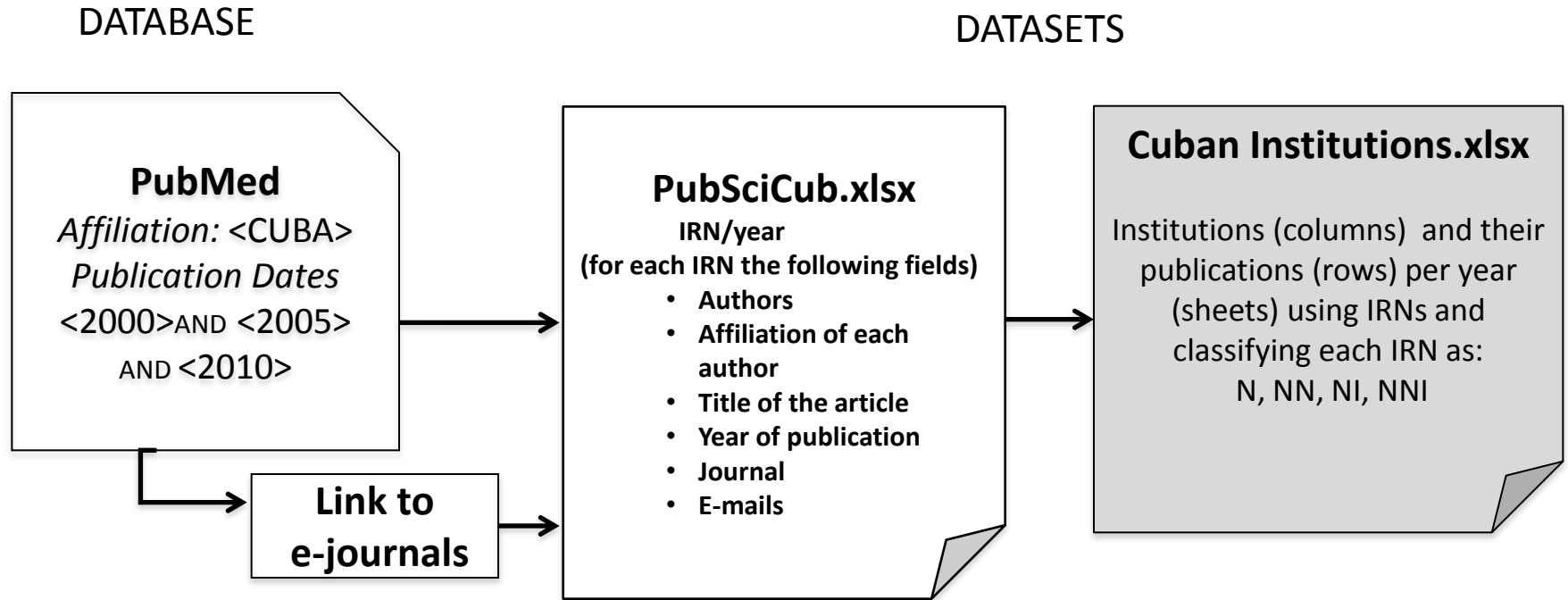


Table 1

Cuban scientific articles in PubMed and those retrieved from electronic journals linked to PubMed (eJ-PubM) indicating the scientific collaboration

Year	Nr articles in PubMed	Nr articles in e-Journals (eJ-PubM)	Non collaborative articles	Collaborative articles	Collaboration (%)
2000	236	147	83	64	43.5
2005	304	241	107	134	55.6
2010	321	258	67	191	74.0
total	861	646	257	389	60.2

For Peer Review

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Table 2

Distribution of Cuban institutions according to the outputs in eJ-PubM and their principal functions

Categories of Institutions	HE (S&T)	HE-Medicine School	Teaching Hospitals	R&D	R&D&P or R&D&S	R&D (non Health related)	Research Institutes/ (Hospital)	Centres aiming to improve Public Health	GH & SH	P / S	Total
Core	6	1	0	2	5	0	6	0	0	0	20
Secondary	2	1	0	1	3	5	13	0	0	0	25
Periphery	4	7	26	12	4	19	12	28	33	11	156

HE: Higher Education

S&T: Science and Technology

R&D: Research and Development

R&D&P: Research, Development and Production

R&D&S: Research, Development and Services

R&S: Research and Services

GH: General Hospitals

SH: Specialised Hospitals (Maternity, Orthopaedic, Children, etc.)

P/S: Production and /or Services

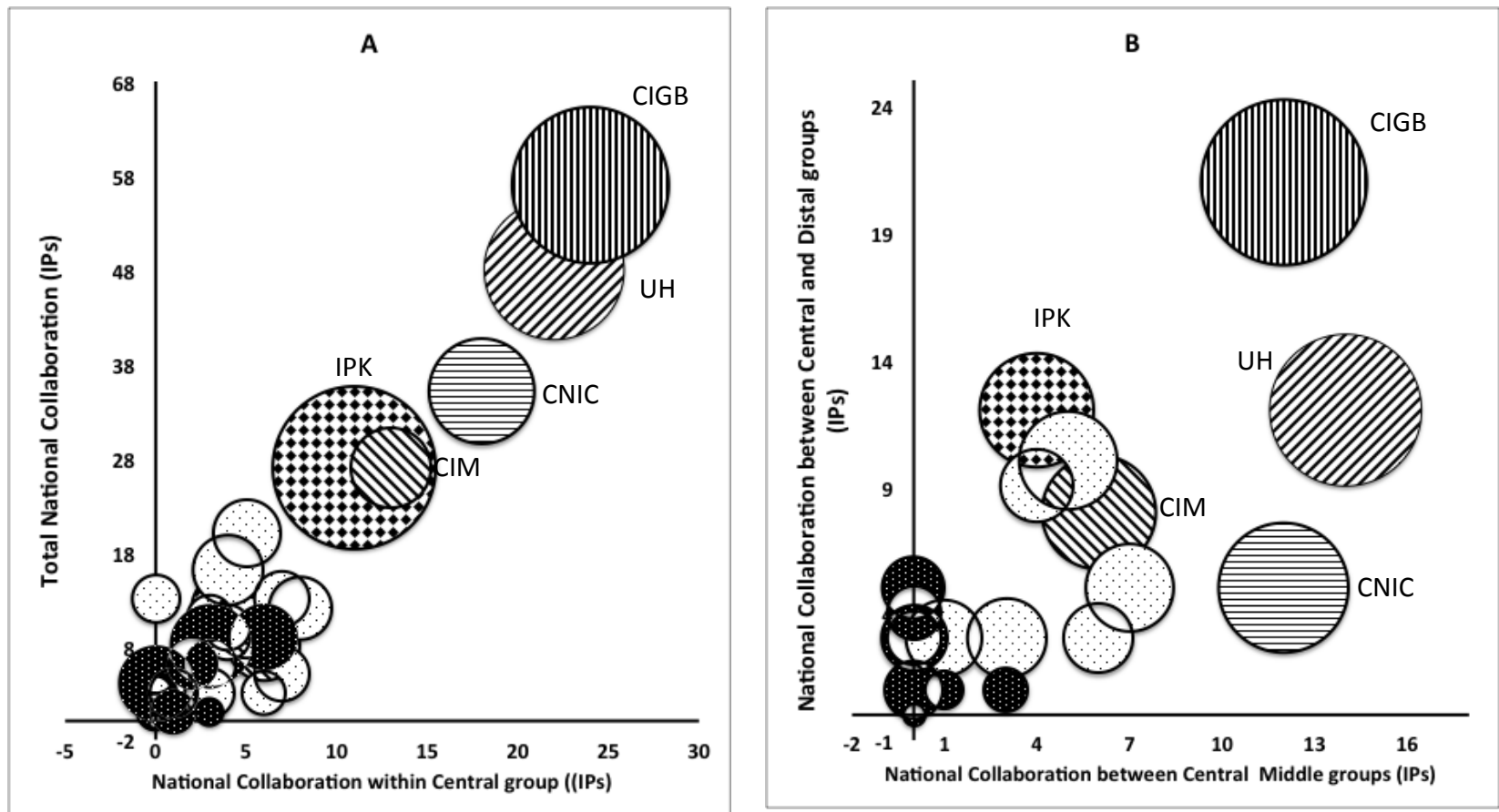
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Table 3
Net and Institutional Publications per group of Cuban Institutions (aggregates for years 2000, 2005, 2010)

Groups	N	TNP	Collaborative (%)	TIP	N	NN	NI	NNI
CENTRAL	205	497	59	630	205	164	144	117
MIDDLE	25	82	70	144	25	72	17	30
DISTAL	27	67	60	206	27	109	18	52
Sub-total	257	646	60.2	980	257	345	179	199

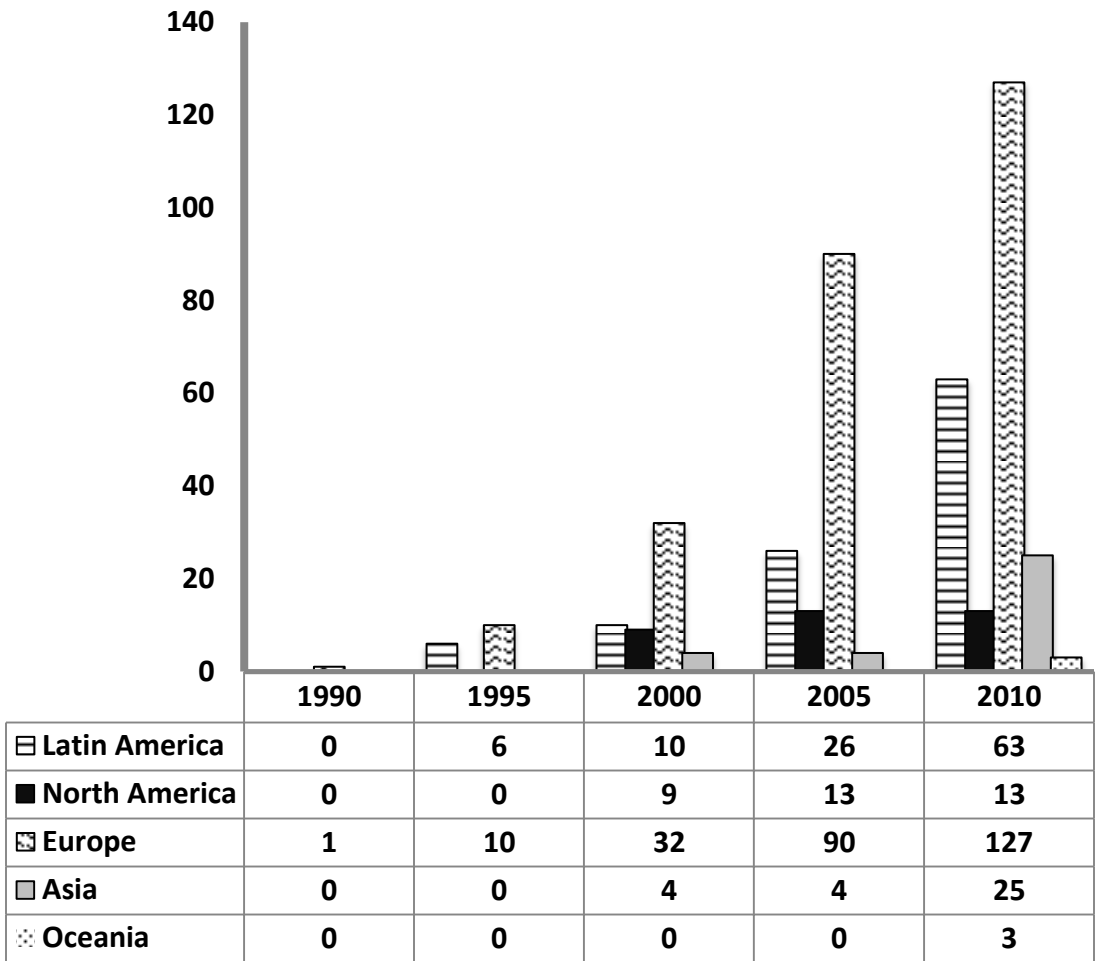
TNP: Total Net Publications; TIP: Total Institutional Publications, N, NN, NI and NNI are types of collaborations (see text)

Figure 2



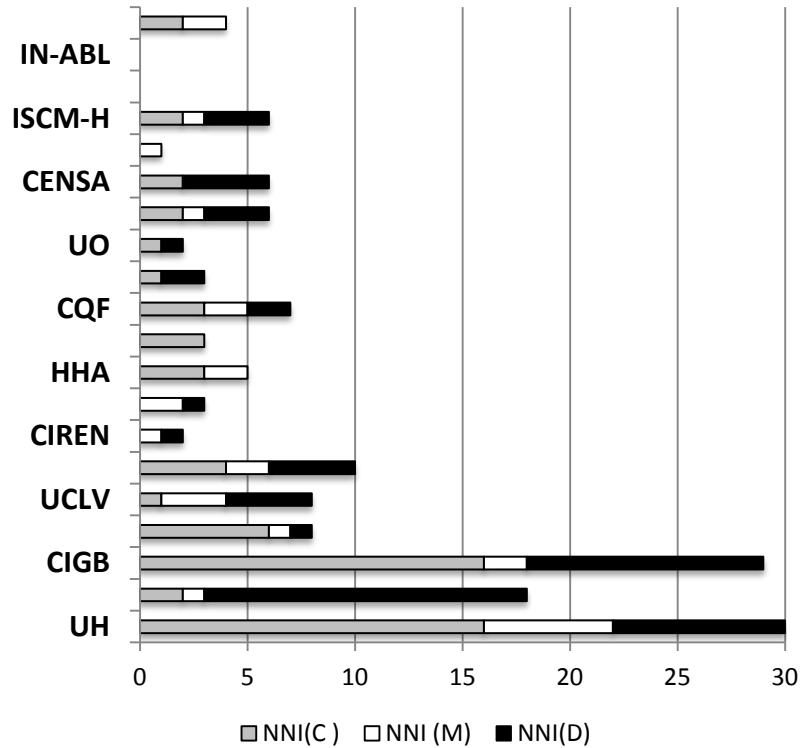
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Figure 3



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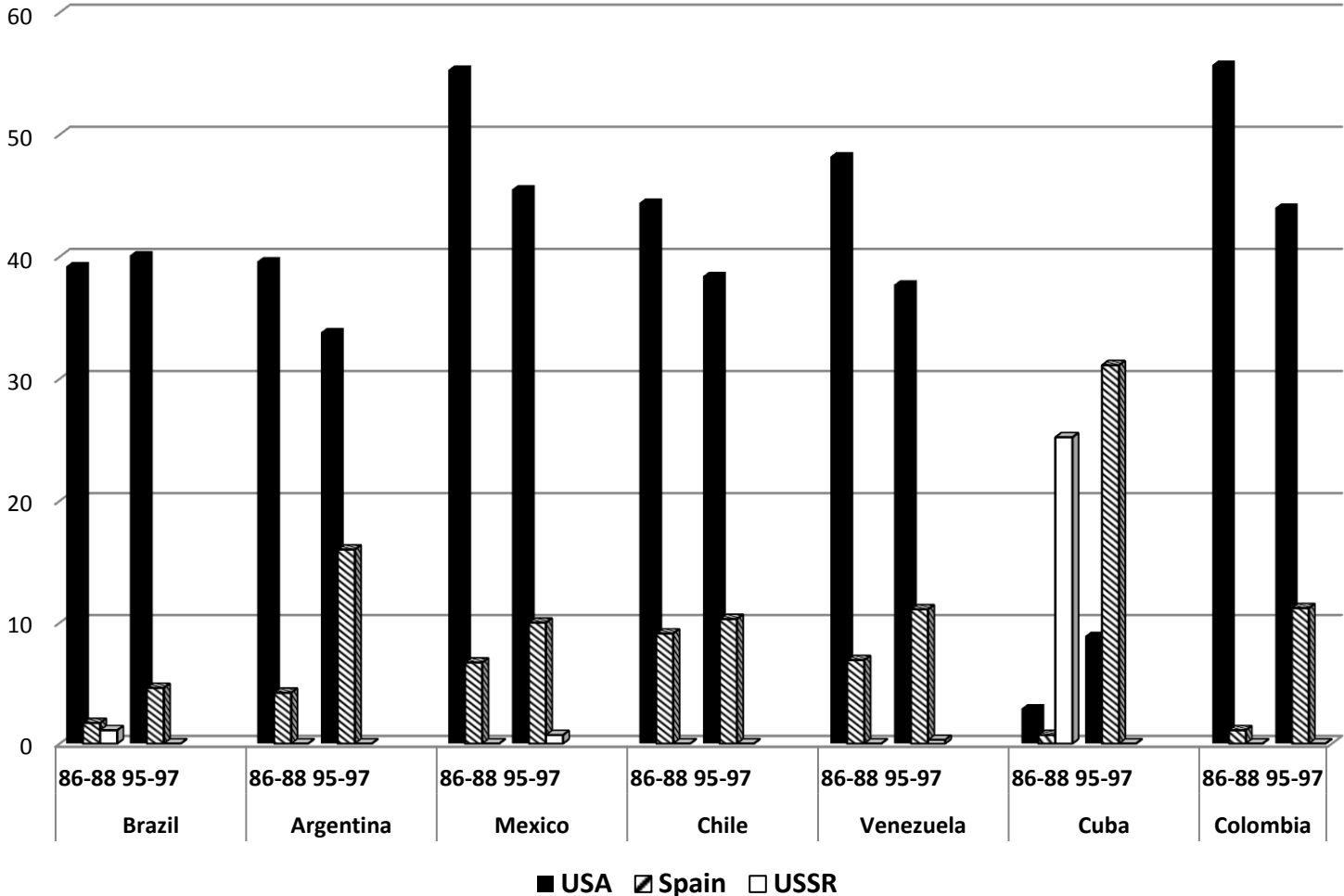
Figure 4



	NNI(C)	NNI(M)	NNI(D)	total papers
UH	16	6	8	104
IPK	2	1	15	141
CIGB	16	2	11	130
CNIC	6	1	1	59
UCLV	1	3	4	36
CIM	4	2	4	34
CIREN	0	1	1	31
INN	0	2	1	26
HHA	3	2	0	24
IF	3	0	0	24
CQF	3	2	2	21
CNC	1	0	2	16
UO	1	0	1	14
InSTEC	2	1	3	14
CENSA	2	0	4	13
INOR	0	1	0	11
ISCM-H	2	1	3	11
CIE	0	0	0	11
IN-ABL	0	0	0	12
UMCC	2	2	0	11

Figure 5. Evolution of international collaboration in Cuban scientific articles at the end of XX century. Internationally coauthored articles (%) in S&E in some countries in Latin America.

Graphic made by the author using data from National Science Foundation (NSF) S&E indicators in 2000. Appendix 6-61 pp. A450-A



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Figure 6

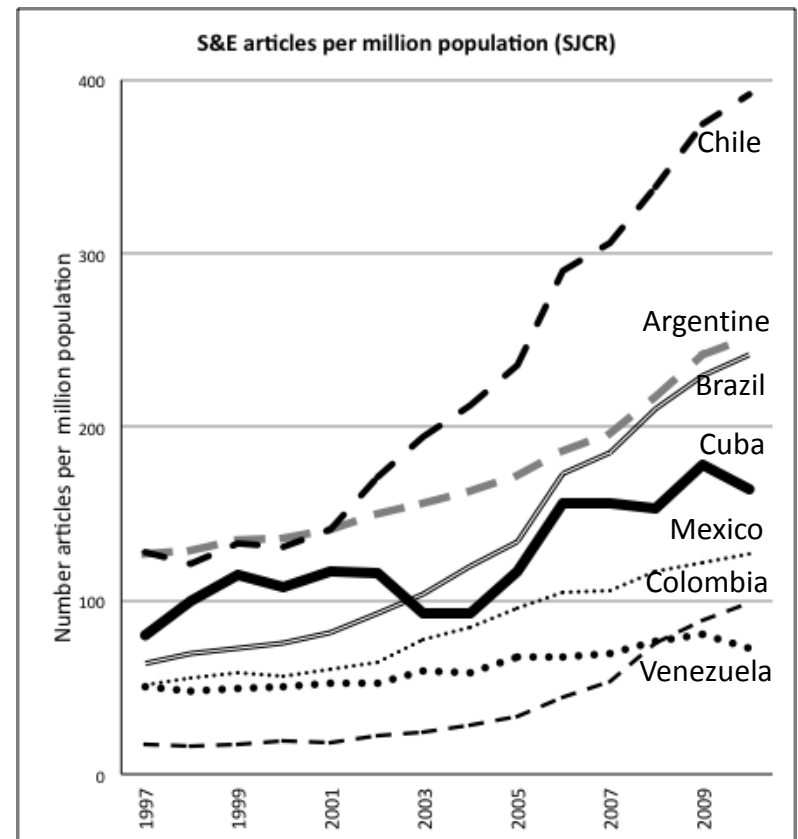
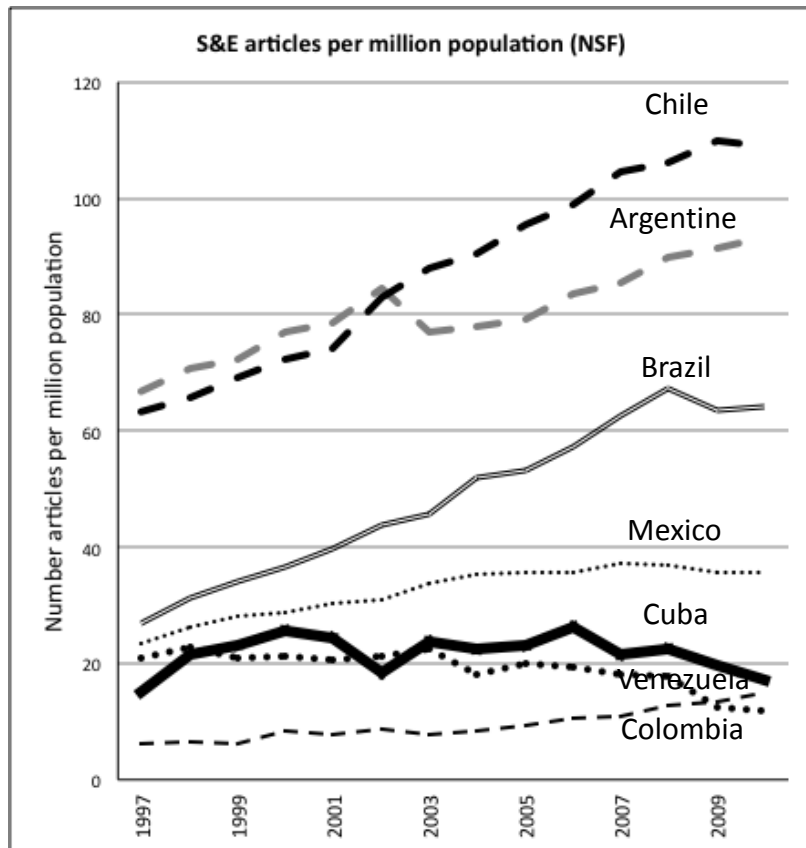


Figure 7

COLLABORATIVE ARTICLES BY DISCIPLINES (Aggregate net publication of year 2000, 2005 and 2010)			
Group of related disciplines	Relevant discipline	All Net Publ (aggreagate)	Collaborative articles
IMMUNOL/ MICROBIOL	IMMUNOLOGY	127	58
	MICROBIOLOGY/PARASITOLOGY		
MEDICINE	CLINICAL MEDICINE	98	47
	EPIDEMIOLOGY		
	DENTISTRY		
	PUBLIC HEALTH		
BIOCHEM/ GENETICS/ MOL BIOL/ BIOTECHNOL	BIOCHEM/BIOPHYS/BIOINF	119	72
	CELL BIOLOGY/MOL BIOLOGY		
	GENETICS		
	GENETIC ENGINEERING		
CHEMISTRY	BIOTECHNOLOGY	104	76
	ANALYTICAL CHEMISTRY		
	PHYS CHEMISTRY		
	MEDICINAL CHEMISTRY		
	CHEM ENGINEERING		
PHYSICS	MEDICAL PHYSICS/ENGINEERING	27	18
	PHYSICS		
MATHEMATICS	BIOSTATISTIC	11	7
	MATHEMATICS		
NEUROSCIENCES	NEUROSCIENCES	37	32
PHARMACOL/ TOXICOL/ PHARMACEUTICS	PHYSIOLOGY	91	54
	PHARMACOLOGY/TOXICOLOGY		
	PHARMACEUTICAL/DRUG DEV		
BIOLOGICAL SCIENCES	PLANT BIOLOGY/ AGRICUL SCI/ VET MED	27	21
	MARINE BIOLOGY		
INF SCIE	INFORMATION SCIENCE	2	1
MULTIDISCIPLINARY	MULTIDISCIPLINARY	3	3
		646	389

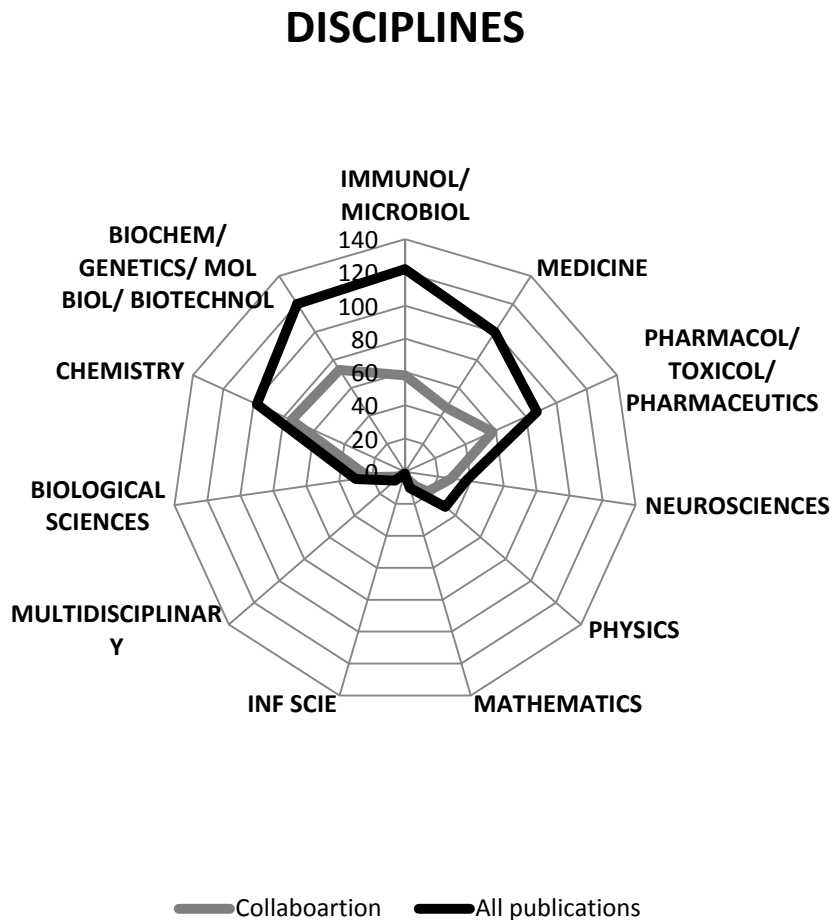
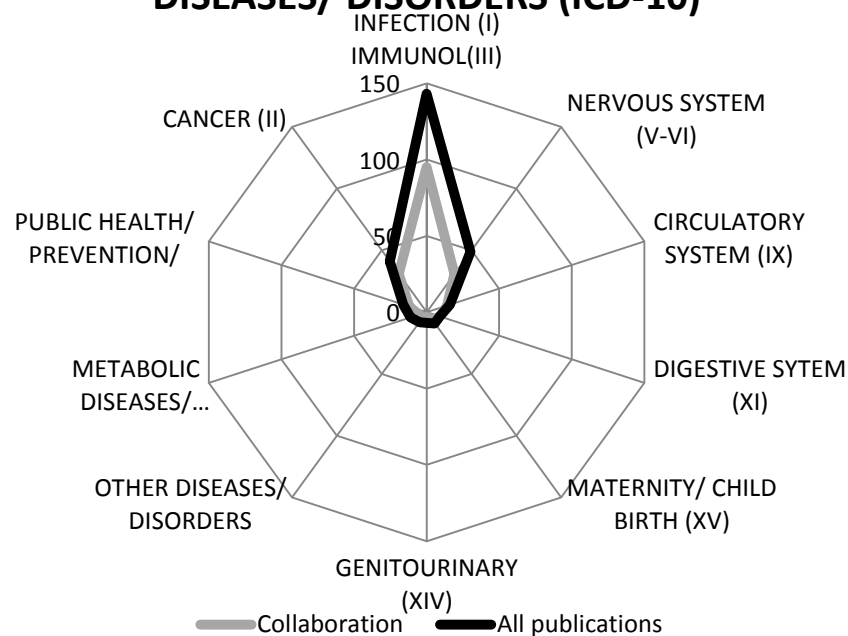


Figure 8

SUBJECT (ICD-10)	Collaborative publications	All publications
INFECTION (I) IMMUNOL(III)	95	143
CANCER (II)	31	41
NERVOUS SYSTEM (V-VI)	31	49
CIRCULATORY SYSTEM (IX)	14	16
METABOLIC DISEASES/ NUTRITION (IV)	5	11
DIGESTIVE SYTEM (XI)	9	9
MATERNITY/ CHILD BIRTH (XV)	6	9
GENITOURINARY (XIV)	3	7
OTHER DISEASES/ DISORDERS	7	8
PUBLIC HEALTH/ PREVENTION/	12	16
	213	309

DISEASES/ DISORDERS (ICD-10)



Appendix 1 Institutions in the Central group

Names of Cuban Institutions (in Spanish), abbreviations and categories (see legend in Table 2)

1. Universidad de la Habana, UH (HE&R)
2. Instituto de Medicina Tropical Pedro Kourí, IPK (R&S)
3. Centro de Ingeniería Genética y Biotecnología, CIGB (R, D&P)
4. Centro Nacional de Investigaciones Científicas, CNIC (R&D)
5. Universidad Central de Villa Clara, UCLV (HE&R)
6. Centro de Inmunología Molecular, CIM (R, D&P)
7. Centro Internacional de Restauración Neurológico, CIREN (R&S)
8. Instituto de Neurología y Neurocirugía, INN (R&S)
9. Hospital Hermanos Amejeiras, HHA (R&S)
10. Instituto Finlay de Investigación y Producción de Vacunas y Sueros, IF (R, D&P)
11. Centro de Química Farmacéutica, CQF (R&D)
12. Centro de Neurociencias de Cuba, CNC (R, D&P/S)
13. Universidad de Oriente Patricio Lumumba, UO (HE&R)
14. Instituto Superior de Ciencias y Tecnologías Aplicadas, InSTEC (HE&R)
15. Centro Nacional de Sanidad Agropecuaria, CENSA (R, D&P/S)
16. Instituto de Oncología y Radiobiología, INOR (R&S)
17. Instituto Superior de Ciencias Médicas de La Habana, ISCM-H (HE&ResMed)
18. Centro de Inmuno Ensayo, CIE (R, D&P)
19. Instituto de Nefrología Abelardo Buch López, IN-ABL (R&S)
20. Universidad de Matanzas Camilo Cienfuegos, UM-CC (HE&R)

Appendix 2 Institutions in the MIDDLE group

Names of Cuban Institutions (in Spanish), abbreviations and categories (see legend in Table 2)

1. Centro de Investigaciones Biológicas, CIB (R, D&S)
2. Instituto Nacional de Endocrinología y Enfermedades Metabólicas, INEEM (R&SH)
3. Centro Nacional para la Producción de Animales de Laboratorio, CENPALAB (R, D&P)
4. Instituto Superior de Ciencias Básicas y pre-Clinicas Victoria de Girón, ISCMpC (HE&R)
5. Centro Nacional Coordinador de Ensayos Clínicos, CENCEC (R&S)
6. Instituto de Cardiología y Cirugía Cardiovascular, (ICCC) (R&SH)
7. Instituto Nacional de Gastroenterología, ING (R&SH)
8. Instituto Nacional Hematología e Inmunología, INHI (R&SH)
9. Instituto de Cibernética, Matemática y Física, ICIMAF (R&D)
10. Centro Nacional de Genética Médica, CNGM (R&SH)
11. Instituto Cubano de Oftalmología, ICO-RPF (R&SH)
12. Centro de Investigaciones Médico Quirúrgicas, CIMEQ (R&SH)
13. Centro de Investigaciones y Asistencia Médica para Ataxia Cubana, CIRAH (R&SH)
14. Instituto Cubano de Investigaciones de los Derivados de la Caña de Azúcar, ICIDCA (R&D)
15. Instituto de Ecología y Sistemática, IES (R&D)
16. Centro de Bioactivos Marinos, CEBIMAR (R&D)
17. Centro de Estudios Aplicados al Desarrollo Nuclear, CEADEN (R&D)
18. Estación Experimental para Caña de Azúcar, Cienfuegos, EECA-C (R, D&P)
19. Instituto Superior Politécnico José Antonio Echeverría, ISPJAE (HE&R)
20. Instituto de Medicina Militar, IMM-LDS (HE&R)
21. Hospital Universitario -Gustavo Aldereguía, HU-GAL (R&GH)
22. Centro de Protección e Higiene de las Radiaciones, CPHR (R&S)
23. Dirección Nacional del MINSAP, DN-MINSAP (R&S)
24. Centro de Investigación y Desarrollo de Medicamentos, CIDEM (R&D)
25. Centro Nacional de Biopreparados, BIOCEN (R, D&P)

Appendix 3 Institutions in the DISTAL group

Names of Cuban Institutions (in Spanish), abbreviations and categories (see legend in Table 2)

1. Centro de Isótopos, CENTIS (R, D&S)
2. Centro Nacional de Bioinformática, NBioC (S&T)
3. Escuela Latinoamericana de Salud Pública, ELAM (R, D&P)
4. Universidad de Ciego de Avila, UNICA (HE&R)
5. Universidad de Cienfuegos, UCF (HE&R)
6. Universidad de Pinar del Río, UPR (HE&R)
7. Universidad Agraria de la Habana y Colegio de Medicina Veterinaria, UACMV (HE&R)
8. Instituto de Oceanología, IO (S&T)
9. Instituto de Geografía Tropical, IGT (S&T)
10. Centro de Ingeniería Genética y Biotecnología-Camagüey, CIGB-Ca (R,D&P)
11. Centro de Ingeniería Genética y Biotecnología-Sancti Spiritu, CIGB-SS (R,D&P)
12. Centro de Reproducción de la Ictiofauna Indígena, CRII (S&T)
13. Centro de Investigaciones de Ecosistemas Costeros, CIEC (S&T)
14. Centro de Estudios Ambientales de Cienfuegos, CEACi (S&T)
15. Centro de Desarrollo de Equipos e Instrumentos Científicos, CDEIC (R&D)
16. Centro de Investigaciones para la Mejora Animal, CIMA (R&D)
17. Centro de Investigaciones Clínicas, CIC (R&S)
18. Instituto de Angiología y Cirugía Vascular, IACV (R&SH)
19. Instituto Nacional de Higiene, Epidemiología y Microbiología, INHEM (R&S)
20. Centro Nacional de Toxicología, CNT (R&SH)
21. Instituto Nacional de Investigación Fundamental en Agricultura Tropical, INIFAT (S&T)
22. Agencia para la Generación de Conocimiento y Tecnología, AGCT (S&T)
23. Museo de Historia Natural Tomás Romay, BIOECO (S&T)
24. Centro de Ingeniería Ambiental-Camagüey, CIA-Ca (S&T)
25. Instituto de Salud Vegetal, ISV (R&D)
26. Instituto de Ciencia Animal, ICA (R&D)
27. Escuela Nacional de Salud Pública, SNSP (HE&R)
28. Instituto Superior de Ciencias Médicas de Villa Clara, ISCM-VC (HE&R)
29. Instituto Superior de Ciencias Médicas de Matanzas, ISCM-Ma (HE&R)
30. Instituto Superior de Ciencias Médicas de Camagüey, ISCM-Ca (HE&R)
31. Instituto Superior de Ciencias Médicas de Santiago de Cuba, ISCM-SC (HE&R)
32. Instituto Superior de Ciencias Médicas de Bayamo, ISCM-Ba (HE&R)
33. Instituto de Nutrición e Higiene de Alimentos, INHA (R&D)
34. Centro Iberoamericano para la Tercera Edad, CITED (R&SH)
35. Instituto de Medicina Legal, IML (R&SH)
36. Instituto de Medicina del Deporte, IMD (R&SH)
37. Centro de Referencia para Investigaciones en Arteriosclerosis, CRIA (R&SH)
38. Centro Nacional de Referencia de Anatomía Patológica, CNRAP (R&SH)
39. Laboratorio de Investigaciones sobre SIDA, LISIDA (R&SH)
40. Centro de Genética Médica _Holguin, CGM-Ho (R&SH)
41. Centro de Investigación sobre Enfermedades Infecciosas, CIEI (R&SH)
42. Hosp. Clínico Quirúrgico Doc. Manuel Asunce Domenech- Camagüey, HCQD-Ca HE&SH)
43. Hospital Universitario Provincial A. Milán Castro-Santa Clara, HUP-VC (HE&SH)
44. Escuela de Medicina de la Habana, Hosp Julio Trigo, EMJT-H (HE&SH)
45. Hospital General Docente Dr. Ernesto Guevara Serna, Las Tunas, HGD-EGS-H (HE&SH)
46. Hosp. Prov. Doc. Clínico Quirúrgico A. Luaces Iraola, Ciego de Avila, HPDCQ-CiAv (HE&SH)
47. Hospital Universitario "Gral. Calixto García", HU-GCG (HE&SH)
48. Hospital General Docente "Carlos J. Finlay", HGD-CJF (HE&SH)
49. Hospital Universitario "Cmdte. Faustino Pérez", HU-CFP (HE&SH)
50. Hospital General Docente Matanzas "J. R. López Tabranes", HGDMa-JRLT (HE&SH)

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51. Hospital General Docente Enrique Cabrera, HGD-EC (HE&S)
52. Hospital Pediátrico Universitario "Pedro Borrás", HPU-PB (HE&SH)
53. Hosp. Pediátrico Universitario-Cienfuegos "P. González Cueto", HPU-PGC-Ci (HE&SH)
54. Hosp. General Docente-Las Tunas "Guillermo Domínguez", HGD-GD-LT (HE&S)
55. Facultad de Ciencias Médicas "Dr. Miguel Enríquez", HGD-DME (HE&S)
56. Hospital Docente Clínico Quirúrgico "10 de Octubre", HCQD-DO (HE&SH)
57. Hospital Pediátrico Docente-Villa Clara "José Luis Miranda", HPD-VC (HE&SH)
58. Hospital Clínico Quirúrgico Docente "Dr. Salvador Allende", HCQD-DSA (HE&SH)
59. Hospital Pediátrico Universitario "Juan Manuel Márquez", HPU-JMM (HE&SH)
60. Facultad de Medicina Finlay-Albarrán, Marianao, HGD-FAM (HE&SH)
61. Clínica Dental Docente "Raúl González Sanchez", CDD-RGS (HE&SH)
62. Clínica Dental Docente de Bauta, CDD-B (HE&SH)
63. Hosp. Clínico-Quirúrgico Docente "Cmdte. Manuel Fajardo", HCQD-MF (HE&SH)
64. Hosp. Quirúrgico Universitario-Pinar del Río "Abel Santa María", HCQD-PR (HE&SH)
65. Hosp. General Docente-Holguín "Vladimir Ilich Lenin" HGD-Ho (HE&S)
66. Hosp. General Docente- Bayamo "Carlos Manuel de Céspedes", HGD-Ba (HE&S)
67. Policlínico Docente- Camagüey "José Martí", PD-Ca (HE&S)
68. Hospital Pediátrico de Camagüey, HP-Ca (S)
69. Cardiocentro-Santa Clara "Ernesto Che Guevara", CC-VC (SH)
70. Hospital Gineco-Obstétrico "Eusebio Hernández", HGO-EH (SH)
71. Hospital Pediátrico de San Miguel del Padrón, HPSMP (SH)
72. Hospital Pediátrico "William Soler", HPWS (SH)
73. Hospital Neumológico Nacional Benéfico Jurídico, HNNBJ (SH)
74. Hospital Psiquiátrico "Eduardo Bernabé Ordaz", HPsEBO (SH)
75. Hospital Psiquiátrico "Gali García", HPsGG (SH)
76. Hospital Provincial de Ciego de Avila, HP-CiA (S)
77. Clínica Central "Cira García", CCCG (SH)
78. Hospital Infantil Sur- Santiago de Cuba, HIS-SC (SH)
79. Hospital Gineco-Obstétrico "América Arias", HGO-AA (SH)
80. Hospital_Santiago Cuba "Conrado Benítez" HCB-SC (S)
81. Hospital Gineco-Obstétrico "R. González Coro" HGO-RGC (SH)
82. Hospital Pediátrico "Leonor Pérez", HP-LP (SH)
83. Hospital "Freire de Andrade", HFA (S)
84. Hospital de Camagüey "María Curie", HMC-Ca (S)
85. Hospital de Villa Clara "Celestino Hernández Robau", HCHR-VC (S)
86. Hospital de Camagüey "Amalia Simoni", HAS-Ca (S)
87. Hospital Rural de Limonar, Matanzas HRL-Ma (S)
88. Hospital de la Isla de la Juventud "Héroes de Baire", HHB-IJ (S)
89. Policlínico de la Isla de la Juventud "Orestes Falls Oñat", POFO-IJ (S)
90. Policlínico de la Isla de la Juventud "J. M. Páez Incháustegu", PJMPI-IJ (S)
91. Policlínico de la Isla de la Juventud "Leonilda Tamayo Matos", PLTM-IJ (S)
92. Centro de Atención Primaria de Salud "Corynthia", CAPS (S)
93. Policlínico "26 de Julio", PVJ (S)
94. Hospital Pediátrico de Centro Habana, HPCH (SH)
95. Clínica Dental de Caimito, CDC (S)
96. Policlínico "19 de Abril", PDA (S)
97. Hospital Pediátrico de Centro Habana, HPCH (SH)
98. Sociedad Cubana de Esclerosis Múltiple, SCEM (R&SH)
99. Laboratorio Central de Criminalística, LCC (R&SH)
100. Centro de Control Estatal de Equipos Médicos, CCEEM (R&S)
101. Centro Nacional para el Control Estatal de la Calidad de los Medicamentos, CECMED (S)
102. Centro Nacional de Información de Ciencias Médicas, CNICS (S)
103. Centro de Protección e Higiene del Trabajo, CNPHT (R&SH)
104. Centro Nacional para la Educación y Promoción de Salud, CNPES (S)
105. Centro para el Desarrollo de la Epidemiología, CDE (R&SH)
106. Unidad Nacional de Salud Ambiental MINSAP, UNASA (R&S)
107. Centro Prov. Santiago de Cuba de Salud Pública y Epidemiología, CPE-SC (R&SH)

108. Centro Provincial de Epidemiología y Higiene, Camagüey, CPHE-Ca (R&SH)
109. Centro Provincial de Epidemiología y Higiene, Habana, CPHE-H (R&SH)
110. Centro Provincial de Epidemiología y Higiene, Villa Clara, CPHEVC (R&SH)
111. Centro Provincial de Epidemiología y Higiene, Ciego de Avila, CPHE-CA (R&SH)
112. Centro Provincial de Epidemiología y Higiene, Santi Spiritus, CPHE-SS (R&SH)
113. Centro Provincial de Homeopatía, Granma, CPH-G (S)
114. Centro Provincial de Homeopatía, Holguín, CPH-H (S)
115. Centro Provincial de Genética Médica-Habana, CPGM-H (R&S)
116. Unidad Prov. de Vigilancia y Lucha Antivectorial, Sancti Spíritu, LAV-SS (S)
117. Unidad Prov. de Vigilancia y Lucha Antivectorial, Santiago de Cuba, LAV-SC (S)
118. Centro Municipal de Higiene y Epidemiología de Bayamo, CMHE-Ba (S)
119. Centro Municipal Vigilancia y Lucha Antivectorial de Boyeros, CMLA-H (S)
120. Centro Municipal Higiene y Epidemiología de Guanabacoa, CMHE-G (S)
121. Centro Municipal de Higiene y Epidemiología de Holguin, CMHE-Ho (S)
122. Centro Municipal de Higiene y Epidemiología de Regla, CMHE-R (S)
123. Centro Municipal de Higiene y Epidemiología de Habana Vieja, CMHE-HV (S)
124. Centro Municipal de Higiene y Epidemiología de Centro Habana, CMHE-CH (S)
125. Centro Municipal de Higiene y Epidemiología de Boyeros, CMHE-Bo (S)
126. Unidad Prov. Vigilancia y Lucha Antivectorial, Cumanayagua, Cienfuegos, LAC-Ci (S)
127. Centro Municipal de Higiene y Epidemiología de Playa, CMHE-PI (S)
128. Centro Municipal de Higiene y Epidemiología de Isla de la Juventud, CMHE-IJ (S)
129. Grupo Empresarial Agromin, GEA (P)
130. Empresa Importadora y Exportadora de Medicamentos y Equipos Medicos, MEDICUBA (S)
131. Laboratorios Biológicos Farmacéutico, LABIOFAM (P)
132. Laboratorios Farmacéutico, AICA (P)
133. Laboratorios MedSOL, MEDSOL (P)
134. Laboratorio de Anticuerpos y Biomodelos Experimentales, LABEX (P)
135. Centro de Química Biomolecular Antígenos Sintéticos, CQB (R&D)
136. Grupo Empresarial de Producciones Biofarmacéuticas y Químicas, GEPBQ (R&D)
137. Laboratorios Farmacéuticos LIORAD, LIORAD (P)
138. Centro de Investigaciones Científicas de la Defensa Civil, CICDC (R&S)
139. Instituto de Investigaciones de Raíces Tropicales, INIVIT (R&D)
140. Instituto de Investigaciones de la Caña de Azúcar, INICA (R&D)
141. Instituto Nacional de Investigación de Sanidad Vegetal, INISAV (R&D)
142. Instituto de Investiagciones del Tabaco, IIT (R&D)
143. Cooperativa Agrícola "Osvaldo Sánchez", Güines, CAIOS-G (P)
144. Estación Experimental Apícola "El Cano", EEA (R&D)
145. Instituto Nacional de Ciencias Agrícolas, INCA (R&D)
146. Centro Nacional de Epizootiología, Diagnóstico e Investigación, CNEDI (R&D)
147. Instituto de Medicina Veterinaria, IMV (R&D)
148. Centro Nacional de Parasitología Animal, CNPA (R&D)
149. Parque Zoológico Nacional, PZN (R&S)
150. Instituto de Investigaciones para la Industria Alimenticia, IIIA (R&D)
151. Centro de Investigaciones Pesqueras, CIPq (R&D)
152. Centro de Investigaciones del Petróleo, CIPt (R&D)
153. Grupo para el Desarrollo Integral de la Ciudad, GGIC (R&D)
154. Centro de Investigación y Desarrollo del Comercio Interior, CIDCI (R&D)
155. Empresa Nacional de Geofísica, ENGf (P)