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Global trends in research resources and scientific output in microbiology in Spain (1998–2007)

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This work assesses the main features of microbiological research developed in Spain over the last decade (1998–2007), observing its changes and trends along the time and comparing them to those which have taken place in other life sciences. This analysis encompasses the entire scientific cycle: the organizations involved (basically, universities, research centers, scientific societies, and companies), resources invested (human and economic), and outputs or results obtained (journals, articles, doctoral theses, and other documents or publications). Summarizing, there is a positive trend in Spanish microbiology regarding research projects and scientific articles; the scientific output (research articles) of Spanish microbiologists ranks 6th in the world, which is higher than the ranking of Spain with respect to economic development.

In today's information society, the cycle of research, development, and innovation (R&D&I) occupies a strategic position, as these components promote scientific knowledge and economic growth in a markedly dynamic international environment. Given the current highly competitive state of R&D&I throughout most of the world, there is a clear need to measure, analyze, and estimate the Spanish R&D&I system in order to gauge its relative position, promote its effective functioning, detect its strengths and weaknesses, improve decision-making, implement changes of orientation in the scientific policies, etc. Methodological handbooks (for instance, *Frascati Manual*, *Oslo Manual*, *Canberra Manual*) published by the Organisation for Economic Co-operation and Development (OECD) [http://www.oecd.org/publications] provide an essential starting point to delimit the collection and interpretation of R&D&I data.

Studying and assessing any research system or any scientific area is not easy due to factors including the diversity of methodologies, classifications, and indicators; the variety and heterogeneity of the information sources; the difficulty in accessing the data; and the imprecise borders between similar areas. From a multidisciplinary perspective, information science can overcome many of these difficulties and improve problem-solving. To achieve an expert approach, documentation specialists must unify, analyze, retrieve and disseminate R&D&I data efficiently, rapidly, and precisely [9]. In information science, however, analyses are commonly limited to bibliometric data arising from scientific output in terms of articles (or "papers"), while other key elements of the R&D&I global cycle tend to be neglected.

A research system is made up of: (i) agents of research (universities, research centers, scientific societies, and companies); (ii) human and economic resources; and (iii) the resulting scientific and technological documentation, often in the form of (iv) scientific journals and articles, or (v) doctoral theses and other documents. Additionally, the study of a research system must adopt both a descriptive and a quantitative approach, based on data provided by public administrations, statistical institutes, observatories (such as the Observatory for Research of the Institute for Catalan Studies, OR-IEC [http://www.iec.cat/or]) and scientific and technological documentation databases. Equipped with this information, scientific experts and policy-makers will be able to carry out significant analyses and thereby make the most appropriate decisions.

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To this end, several methodological considerations should be taken into account. In some cases, the heterogeneity or lack of information sources can lead to differences in the periods analyzed or in classifications. Furthermore, the keyword searches produce imprecise but interesting results from the point of view of global tendencies. Finally, in-depth studies of private universities and foundations are not always available.

Agents of microbiological research

Public universities. In the area of higher education, Spain has currently 47 public universities and 22 private universities. The field of microbiology is present in most of the institutions that have life-sciences faculties or centers. Searching for the term "microbiolog*" in the name of departments in public universities, only 22 of those universities have departments related to the term [5]. Obviously, this search term excludes areas or sections of microbiological research in larger departmental or organizational units in many of the remaining Spanish universities, most of which offer studies in different microbiological disciplines, both basic (microbial ecology, genomics, taxonomy, etc.) and applied (food science and technology, bioremediation and biodeterioration, epidemiology, etc.).

Public research centers. Most research centers have units devoted to microbiological studies, too. For instance, one aim of the National Microbiology Center (CNM, Madrid) of the Carlos III Health Institute [http://www.isciii.es] is "to study different aspects related to human infectious diseases". The National Institute for Agricultural and Food Research and Technology (INIA) [http://www.inia.es] carries out research in microbiological food safety and related areas. There is also the Center for Astrobiology (CAB, Torrejón, Madrid) [http://cab. inta.es], in Torrejón (Madrid), where several groups work in the field of microbial ecology. In addition, the Spanish National Research Council (CSIC) [http://www. csic.es] promotes lines of microbiological research in various centers, including the Center of Biological Research (CIB, Madrid), the National Center of Biotechnology (CNB, Madrid), the Institute of Plant Biochemistry and Photosynthesis (IBVF, Seville), the Institute of Marine Sciences (ICM, Barcelona), the Institute of Marine Research (IIM, Vigo), the Center for Advanced Studies (CEAB, Blanes), the Institute of Industrial Fermentations (IFI, Madrid), the Institute of Biochemical Microbiology (IMB, Salamanca), the Institute of Agrobiotechnology (IdAB, Mutilva Baja, Navarra), the Institute of Natural Resources (IRN, Madrid), and the Institute of Natural Resources and Agrobiology (IRNASA, Salamanca, and IRNAS, Seville).

Scientific societies. They are several learned scientific societies in Spain devoted specifically to microbiology. The oldest is the Spanish Society for Microbiology (SEM) [http://www.semicro.es], founded in 1946 with the aim of fostering and promoting the field of microbiology. It is an interdisciplinary society, made up of scientists who work in the many different disciplines that constitute microbiology. Other microbiology societies in Spain must also be highlighted: the Spanish Society of Immunology (SEI), founded in 1975 [http://www. inmunologia.org]; the Spanish Association of Mycology (AEM), founded in 1977 [http://www. revibero ammicol.com /AEM]; the Spanish Society of Infectious Diseases and Clinical Microbiology (SEIMC), founded in 1981 [http://www. seimc. org]; the Spanish Society for Virology (SEV), founded in 1987 [http://www2.cbm.uam.es/sev]; and the Spanish Society of Chemotherapy (SEQ), founded in 1987 [http://www.seq.es].

Companies. The Survey on Technological Innovation in Companies, prepared in 2006 by the Spanish Institute of Statistics (INE) [http://www.ine.es], identified 659 companies that carried out activities related to biotechnology, but only 70 of these were large companies with more than 250 employees, especially in the pharmaceutical (e.g., Grífols, Laboratories Dr. Esteve, Group Uriach, Italfarmaco) and agrifood (e.g., Danone, Food & Beverages Pascual Dairy, Puleva) sectors. Of these companies, 115 are members of the Spanish Association of Biocompanies (ASEBIO) [http:// www.asebio.com] [2]. Spin-off companies derived from research developed in universities and public research centers must also be taken into account. Some of these have proven to be amongst the most dynamic biotechnological companies in Spain, for instance: Advancell, Araclon Biotech, Bio-Ges Starters, Genetrix, Mellitus, Neocodex, Oryzon, and Genomics.

Human and economic resources

The Spanish Ministry of Science and Innovation (MICINN) [http://www.micinn.es] tracks the educational and research staff of Spanish public universities in different areas of knowledge, among which the life sciences are well-represented. For instance, Cellular biology corresponds to "area 50", Biochemistry & Molecular biology, corresponds to "area 60", Genetics, to "area 420", Immunology, to "area 566", and Microbiology, to "area 630" [see http://tinyurl.com/4hrp5r]. The educational and research staff of the Spanish public universities in those areas increased in absolute numbers during the period 1998–2006. However, the accumulated growth rate in microbiology (6.51%) was clearly lower than that in other above

Table 1. Educational and research staff of Spanish public universities (1998–2006)

Academic year	Total[a]	Cellular biology (Area 50)[b]	Biochemistry & Molec. biology (Area 60)	Genetics (Area 420)	Immunology (Area 566)	Microbiology (Area 630)
1998–1999	76,157	433	968	330	67	661
1999–2000	79,779	446	1016	355	79	678
2000–2001	82,902	451	1044	367	81	693
2001–2002	84,645	442	1050	371	89	682
2002–2003	86,676	457	1049	374	89	688
2003–2004	88,222	450	1069	384	100	690
2004–2005	91,059	480	1075	388	99	687
2005–2006	91,798	485	1091	403	107	704

[a]Total educational and research staff of Spanish public universities.
[b]See text for knowledge areas at the Spanish public universities.
Source: Spanish Institute of Statistics (INE) [http://www.ine.es].

mentioned areas (16.02% globally) and lower than in Spain globally (20.54%) (Table 1).

In relation to economic resources, it is necessary to mention research projects funded by the National R&D&I Plan (2004–2007) [http://www.micinn.es/planidi] and targeted to universities and public research centers. According to a documental search for Spanish keywords ("microbiolog* or microorganism* or prion* or virus* or bacteri* or levadur* or hong* or protist* or alga*") in the titles of the 12,745 projects granted, 439 activities (3.44% of the total) were related to microbiology research. In the distribution of Spanish programs (Table 2) the projects from the program "Agrifood resources and technology" placed first (in number of projects and economic resources), followed by those projects from the program "Fundamental biology" and "Biotechnology". The grants amounted to 56.2 million euros (4.16% of the total).

Concerning the companies, in 2006 biotechnological firms had revenues exceeding 22,500 million euros and employed approximately 88,100 people. Internal R&D biotechnology expenses grew by 46% compared to 2005, reaching 300 million euros. In terms of the number of biotechnology companies, the most dynamic regions are Catalonia (23.67% of the total), Madrid (15.33%), Andalusia (10.32%), and the Basque Country (9.56%) [2].

Scientific and technological documentation

Through the activities of R&D&I, new knowledge is promoted, which is presented through public and specialized documents [9]. Recently, there has been a change in the paradigm of scientific documentation, due to the vertiginous speed of contemporary research in almost all fields of knowledge and to the rapid transmission of research results published in journal articles or in congress proceedings. In addition, information and communication technologies (ICT) and open access policies have had a huge impact on the production and diffusion of scientific knowledge [8]. Currently, R&D&I activities generate very diverse types of documents, whose content is spread through highly diverse channels, in different versions (notes, summaries, drafts, documents pending publication, pre-prints, proofs, etc.), and with different access levels (open or payment, public or restricted, total or partial, etc.). Consequently, analyses of scientific and technological documentation must be improved; for example, the current, restricted concept of bibliometrics, i.e., simple numerical calculations derived from the study of certain

Table 2. Life sciences and related fields projects[a] funded by Spanish programs (2004–2007)

National program	Projects	Million €
Agrifood resources and technology	163	18,449
Fundamental biology	87	14,541
Biotechnology	60	9739
Biodiversity and Earth sciences	44	3536
Biomedicine	32	4510
Environmental sciences and technology	24	2433
Chemical sciences and technology	16	1845
Others	13	1114
Total	439	56,167

[a]See text for microbiology research projects.
Source: Spanish Ministry of Science and Innovation [http://www.micinn.es].

Table 3. Main microbiology journals in Spain

Title	ISSN	Present publisher	Started	Issues/yr	JCR2007 IF
Enfermedades Infecciosas y Microbiología Clínica	0213-005X	Elsevier/Doyma, Barcelona	1983	10	1.096
Revista Iberoamericana de Micología	1130-1406	Spanish Association of Mycology, Bilbao	1990[a]	4	–
International Microbiology	1139-6709	Viguera, Barcelona	1998[b]	4	2.617

[a]Founded in 1984. From 1984 to 1989, the journal was named *Revista Ibérica de Micología*.
[b]Founded in 1947. From 1947 to 1986, the journal was named *Microbiología Española*. From 1985 to 1997, the journal was named *Microbiología SEM* [see ref. 7].
Source: Latindex [http://www.latindex.unam.mx], CSIC bibliographic databases [http://bddoc.csic.es:8080] and searches by the Observatory for Research (OR-IEC) [http://www.iec.cat/or].

types of scientific documents, is no longer adequate. A more extensive definition, one that takes the global cycle of R&D&I into account, is necessary. As a starting point, we can study the contributions of Callon et al. [3], who described scientometrics as the quantitative examination of scientific and technological research; that is, the resources, results, and organizational framework of the generation of knowledge. According to these authors, it is necessary to scientifically study research in order to promote it, meaning that the scientific method must be rigorously applied to analyzing scientific information.

The current volume of scientific output is immense. To study it, quantitative techniques of analysis that focus mainly on the documents produced by academic research and industrial innovations are needed. The reasons for restricting the analysis to this group of documents include: easy access to the documents; high-level coding, which facilitates processing; and proximity to the elaboration of new knowledge. However, Callon et al. [3] insisted that "this does not allow us to forget that other documents deserve to be analyzed and that, in the same way that we do with literature, we should consider personnel, tools, and technical devices, as well as financial resources and their flow". Caution in some aspects is also advisable, since scientometric tools have important limitations. Interdisciplinary studies promote research in cooperative networks and are thus crucial in contemporary science. Any quantitative approach has to be complemented with qualitative criteria, and each case must be examined by experts in the specific field.

Scientific journals and articles

A basic task of researchers is reading and writing technical documents, especially articles published in peer-reviewed journals. Currently, articles may have an independent life from the journals in which they are published, because they are distributed independently in the form of individual "reprints" (now, electronic) [7]. The quality of the produced knowledge (articles, or "papers") is guaranteed through debate and criticism by the international scientific community. In this sense, "biomedical scientists place a high value on the traditional roles of the journal in providing certification and validation of their work, and the peer review system appears to be functioning very effectively: internationally, 84.6% agreed that the reviewers had improved the quality of their last article" [11].

Three major microbiology journals are currently published in Spain (Table 3). In addition, there are several societal bulletins and newsletters (*Actualidad SEM*, *Boletín de noticias SEIMC*, *Virología*, etc., both printed and electronic), that are published by scientific societies. Furthermore, other Spanish science journals cover a broad range of topics and occasionally publish the results of microbiological research (Table 4).

Bibliometric analyses provide quantitative and qualitative elements essential to the assessment of scientific developments. They provide insight into the structure and dynamics of science and technology systems, determine a country's standing in international science rankings, and highlight geographical areas with different degrees of specialization and centers of excellence [4]. However, up-to-date, international bibliometric studies on articles published in microbiology journals are scarce [1,11–13].

The publication of Spanish microbiology articles in internationally indexed journals presents a positive trend, as evidenced by bibliometric data on articles published in the categories of Microbiology and Biotechnology & Applied Microbiology in the Science Citation Index (SCI-Expanded, Thomson) database [6] (Table 5). In absolute numbers, in terms of percentage, and in citations per article, the number of microbiology articles has increased, especially since 2003. In order to evaluate homogeneous data, only citations received in three years (i.e, the year of publication and the

Table 4. Spanish scientific journals that occasionally publish articles related to microbiology

Title	ISSN	Present publisher	Started	Issues/year	JCR2007 IF
Medicina Clínica	0025-7753	Elsevier/Doyma, Barcelona	1943	40	1.337
Grasas y Aceites	0017-3495	Fat Institute (CSIC), Madrid	1950	4	0.319
Archivos de Zootecnia	0004-0592	University of Córdoba, Córdoba	1952	4	–
Alimentaria	0300-5755	Ediciones y Publicaciones Alimentarias (EYPASA), Madrid	1964	10	–
Alimentación, equipos y tecnología	0212-1689	Reed Business Information, Madrid	1982	10	–
Inmunología	0213-9626	Spanish Society of Immunology, Barcelona	1982	4	–
Limnetica	0213-8409	Iberian Association of Limnology, Valencia	1984	2	–
Phytoma España	1131-8988	M.V. Phytoma España, Valencia	1988	10	–
Revista Española de Quimioterapia	0214-3429	Thomson/Prous Science, Barcelona	1988	4	–
Scientia Marina[a]	0214-8358	Institute of Marine Sciences (CSIC), Barcelona	1988	4	0.945
Journal of Investigational Allergology & Clinical Immunology	1018-9068	Thomson/Prous Science, Barcelona	1991	4	–
Research and Review in Parasitology[b]	1133-8466	Spanish Society of Parasitology, Madrid	1991	4	–
Food Science and Technology International[c]	1082-0132	Institute of Agrochemistry and Food Technology (CSIC), Valencia	1995	6	0.632
Ciencia y Tecnología Alimentaria	1135-8122	Association of Food Science and Technology of Galicia (ALTAGA), Santiago de Compostela	1995	2	0.941
Alergología e Inmunología Clínica[d]	1575-734X	Group Saned, Madrid & Spanish Society of Allergology and Clinical Immunology, Barcelona	1999	6	–
Contributions to Science	1575-6343	Institute for Catalan Studies, Barcelona	1999	2	–

[a]From 1955 to 1988, the journal was named *Investigación Pesquera*. In 1994 and 1995, it published two issues per year.
[b]From 1941 to 1990, the journal was named *Revista Ibérica de Parasitología*.
[c]From 1992 to 1994, the journal was named *Revista Española de Ciencia y Tecnología de Alimentos*.
[d]From 1986 to 1998, the journal was named *Revista Española de Alergología e Inmunología Clínica*.
Source: Latindex [http://www.latindex.unam.mx], CSIC bibliographic databases [http://bddoc.csic.es:8080] and searches by the Observatory for Research (OR-IEC) [http://www.iec.cat/or].

two following years) are counted by the SCI-Expanded (therefore, data for 2006 and 2007 in Table 5 are not complete). In relation to distribution of articles per sector (only data from research entities with an output of more than 15 articles in the period 1997–2007 have been selected), the scientific output of universities (67.23%) clearly predominated over the years 1997–2007, followed by public research centers (23.17%) and hospitals (8.56%). In contrast, the output of companies, non-profit organizations, foundations and private research institutions, was, in terms of the number of scientific articles, very low, only 1.04%.

According to the Essential Science Indicators (ESI, Thomson) database (Table 6), regarding the international comparison of the output of scientific articles in microbiology, Spain ranks sixth in number of documents and eighth in number of citations received during the period 1998–2008. These positions are better than those in the fields of Biology & Biochemistry and Molecular biology & Genetics. Furthermore, compared to the rest of the countries in Table 6, microbiology in Spain has the greatest proportion of articles and citations with respect to global output in the other analyzed scientific fields.

Doctoral theses and other documents

Doctoral theses, which must be original works in their fields, provide a faithful image of the new, more open approach of research. They also serve as good indicators of the potential of researchers' training and of their scientific output. For doc-

Table 5. Bibliometric data about Spanish scientific articles in SCI–Expanded (Thomson) database (1997–2007)

Year	Spanish articles	Microbiology articles	Percentage	Citations (3 years)	Citations per article
1997	18,403	793	4.31%	2918	3.68
1998	19,670	850	4.32%	3071	3.61
1999	20,900	919	4.40%	3748	4.08
2000	21,040	916	4.35%	3901	4.26
2001	22,342	990	4.43%	3984	4.02
2002	23,621	1043	4.42%	4031	3.86
2003	24,709	1095	4.43%	5357	4.89
2004	26,433	1212	4.59%	6224	5.14
2005	28,438	1272	4.47%	7050	5.54
2006	30,613	1313	4.29%	4929	3.75
2007	32,381	1364	4.21%	1684	1.23

Source: SCI-Expanded (Thomson) [http://scientific.thomsonreuters.com/products/sci].

toral theses, the Spanish Ministry of Science and Innovation has set up a doctoral theses database TESEO [https://www.micinn.es/teseo], with a search procedure analogous to that based on the titles of research projects. The data show a downward trend in the relative proportion of total/microbiology theses (Table 7). In absolute numbers, the 1309 doctoral theses on microbiology topics corresponded to 2.18% of the total output in Spain. Indeed, these numbers are lower

Table 6. International scientific output (research articles and citations) of Microbiology, Biology & Biochemistry, and Molecular biology & Genetics in Spain (January 1998–June 2008). Countries are ordered by total number of scientific articles published

Microbiology			Biology & Biochemistry			Molecular biology & Genetics		
Country	Articles[a]	Citations	Country	Articles	Citations	Country	Articles	Citations
USA	52,501	1,051,538	USA	200,108	4,431,155	USA	118,848	3,832,924
Germany	14,784	250,822	Japan	61,144	816,482	Germany	25,753	696,749
Japan	13,581	148,323	Germany	44,046	800,792	Japan	25,325	542,675
England	11,972	227,464	England	40,058	803,835	England	23,436	740,768
France	11,506	193,054	France	34,545	535,988	France	18,353	468,540
Spain	6983	80,166	Canada	25,957	449,734	Canada	13,791	354,565
Canada	6190	96,416	Italy	23,316	288,229	Italy	11,466	228,782
Italy	5103	55,653	P R China	21,645	121,497	Netherlands	7298	195,040
Netherlands	4754	89,140	Spain	15,403	187,235	Spain	7289	137,804
Australia	4648	71,861	Australia	14,807	237,019	Australia	6787	155,864
Switzerland	3126	61,032	Sweden	13,451	233,308	Switzerland	6488	208,782
Scotland	3114	52,985	Netherlands	12,121	220,316	Sweden	5426	139,242
Sweden	3041	48,271	Switzerland	10,438	234,835	Scotland	4557	143,370
Belgium	2911	49,737	Denmark	7843	136,656	Israel	3709	112,935
Denmark	2197	41,669	Scotland	7518	155,030	Belgium	3613	84,337

[a]In the ESI counts, the term used is “papers”.
Source: Essential Science Indicators (ESI, Thomson) [http://scientific.thomsonreuters.com/products/esi/].

Table 7. Doctoral theses finished in Spain (1997–2007)

Academic year	Total theses	Microbiology theses[a]	Percentage
1997–1998	5679	131	2.31%
1998–1999	5004	137	2.74%
1999–2000	5861	125	2.13%
2000–2001	5906	148	2.51%
2001–2002	6381	147	2.30%
2002–2003	6629	128	1.93%
2003–2004	7458	153	2.05%
2004–2005	6302	137	2.17%
2005–2006	5822	108	1.86%
2006–2007	4946	95	1.92%

[a]See discussion in the text.
Source: TESEO doctoral theses database from the Spanish Ministry of Science and Innovation [https://www.micinn.es/teseo].

than the actual figures, because the classification system of the field(s) in which the doctoral theses were produced is neither optimal nor exhaustive; consequently, quite a number of theses with microbiology-related content are not identified as such. In addition to the usual keywords employed to detect such theses, it would be convenient to use other, more direct approaches, such as detecting scientific (Latin) names, but this would imply the necessity that for a detailed analysis in a specific field, specialists in that field and in the field of documentation must work shoulder to shoulder.

A patent is a public document describing novel technical features of products or industrial processes that are protected for a period of time in a geographical area. The dimensions of legal protection and of public transmission are intertwined, since the right of exploitation is safeguarded legally in an exchange that favors technological progress. In the International Patent Classification (IPC) [http://www.wipo.int/classifications/ipc/en], the C12 subsection (Biochemistry; Beer; Spirits; Wine; Vinegar; Microbiology; Enzymology; Mutation or Genetic Engineering) comprises a significant number of technological inventions derived from research in microbiology. Local patent applications in the Spanish Office of Patents and Trade Marks (OEPM) (Table 8) clearly prove that this is an expanding field. In this same sense, the Circle for Innovation in Biotechnology of the Region of Madrid (CIBCM), in collaboration with ASEBIO [2], recorded 144 biotechnological inventions (applications and concessions by Spanish companies) in 2007, a 14% increase compared to 2006.

Anyway, it must be remembered that this increase has occurred in the context of a traditional endemic deficit in Spain in the awarding of patents. This deficit underlines the need for an interconnection between the scientific capacities of the public and those of the private system, with the goal to increase the number of Spanish patents and to set up technology companies that are competitive with those elsewhere in the European Union [10].

In addition to the generation of patents, R&D&I activities produce an enormous number of documents that are difficult to access (preprints, congress proceedings, research or technical reports, working papers, etc.), which results in problems of preservation and visibility. On the fringe of commercial databases, some solutions to these problems have appeared; for example, the portal RECOLECTA: Open Science Harvester [http://recolecta.net] is a joint initiative of the Spanish Academic Libraries Network (REBIUN) and the Spanish Science and Technology Foundation (FECYT). RECOLECTA's main goal is to promote open access publication of the papers developed at 69 Spanish universities and to facilitate their use and visibility. It has thus far gathered 326,017 documents, 2955 (0.91%) of which include some of the keywords already used in searches addressing research projects and doctoral theses.

Table 8. Spanish Office of Patents and Trade Marks (OEPM) patent applications (1999–2005)

Year	Spanish patents	C12 patents	Percentage
1999	2859	40	1.40%
2000	3111	38	1.22%
2001	2904	33	1.14%
2002	3055	49	1.60%
2003	3081	47	1.53%
2004	3100	61	1.97%
2005	3252	69	2.12%

Source: OEPM [http://www.oepm.es].

Final considerations

The importance of R&D&I activities is obvious in today's extremely competitive world. The creation of knowledge and its coupling to the industrial production represent a decisive advantage. In this context, a robust, relevant, and comparable body of information must be available to make the most appropriate decisions affecting management and R&D&I policies. Ultimately, the goal is to promote progress in science and technology.

The description, study, and appraisal of any R&D&I system is a complex task. Nevertheless, it is clear that any analysis must reflect the entire cycle, rather than restrict itself to only part of the resources or results, and must therefore be quantitative as well as qualitative in its examination.

This article has provided an overview of the state of the art of microbiology research and its evolution in relation to Spanish scientific activity. Further studies should address elements such as territorial or institutional distribution, and areas of specialization; collaborative networks among researchers, fields, sectors, and countries; the role of the private sector in scientific and technological research; and the development of more straightforward methodologies for data searches and interpretation as well as their integral analysis.

In conclusion, Spanish microbiology shows a slight downwards trend in the number of researchers in public universities and in the training of new researchers, as reflected by the number of doctoral theses. This trend, however, contrasts with the positive evolution in research projects, scientific articles, and the development of biotechnology companies. Furthermore, the production of scientific articles by Spanish microbiology ranks sixth in the world, much above the economic level of the country and clearly higher than several other fields of life sciences, such as Biochemistry and Molecular biology. Understanding the causes of those phenomena would help policy-makers to implement appropriate measures to further improve microbiology and to consolidate the positive aspects of scientific research and production in Spain.

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