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Assessment of the scientific-technological production in molecular biology in Brazil (1996-2007): the contribution of genomics programs

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ABSTRACT

Several genome sequencing programs were launched in Brazil by the end of the nineties and the early 2000s. The most important initiatives were supported by the ONSA program (http://watson.fapesp.br/onsa/Genoma3.htm) and aimed at gaining domain in genomic technology and bringing molecular biology to the state of art. Two main sets of data were collected in the 1996-2007 period to evaluate the results of these genome programs: the scientific production (Scopus and Web of Science databases) and the register of patents (US Patent and Trademark Office), both related to the progress of molecular biology along this period. In regard to the former, Brazil took a great leap in comparison to 17 other developed and developing countries, being only surpassed by China. As to the register of patents in the area of molecular biology, Brazil's performance lags far behind most of the countries focused in the present study, confirming the Brazilian long-standing tendency of poor achievements in technological innovations when compared with scientific production. Possible solutions to surpass this inequality are discussed.

Key words: science assessment, genomics, scientometrics, molecular biology.

INTRODUCTION

Molecular biology of the gene is an area of contemporary science that permeates several other areas of life sciences. Its concepts and methods have been, for historical reasons, slowly absorbed by the Brazilian Scientific community. For example, in the period of 1965-1975 the ISI-Thomson Reuters database registered 24 articles published in Brazil in this area, involving approximately ten groups (search for key words expression described below). The authors belonged mainly to the areas of cytology and biochemistry, and the tendency was for a more descriptive study. In the same period, the United States published 6439 articles and a great number of them came from laboratories with competent groups in genetics, microbiology, virology and enzymology, which were the truly propelling areas of studies in molecular biology of the gene (Judson 1979). The lack of research groups in Brazil with proficiency in these areas was certainly a decisive factor for the slow progress of molecular biology in the following decades.

Taking these circumstances into consideration, this work aims at describing the evolution of scientific-technological production in molecular biology in Brazil and comparing it to international results, focusing the period of 1996-2007. The interpretation of the results related to such evolution was performed by investigating the impact of the implementation of genomics national programs, highlighting the production in the

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state of São Paulo, in view that it was the first one to launch these programs through the ONSA-FAPESP initiative (http://watson.fapesp.br/onsa/Genoma3.htm). In defense of the implementation of the ONSA genomics programs, there was the proposal of rescuing molecular biology (Perez 2002), maybe more important than genome sequencings themselves. The success of the latter is evident through the publications that they originated. What is less clear is how much such effort meant in terms of a molecular biology advance in Brazil. The recovery of information related to the national scientific production shows that the molecular biology area has achieved a very meaningful growth in Brazil. The fact that countries that had not launched genomics programs did not reach such leaps in molecular biology publications reinforces the assumption that Brazilian genomic programs (Simpson et al. 2000, Silva et al. 2002, Brazilian Genome Project Consortium et al. 2003) were fundamental for this progress. However, no technological spin off developments occurred paralleling the scientific progress and, therefore, the great impulse in molecular biology had no impact in terms of technological innovations.

METHODOLOGY

In order to retrieve scientific publications related to the molecular biology area, the SCOPUS database has been used. It was selected for its large coverage of high-impact journals in life sciences. The use of ISI-Thomson Reuters database was impaired due to the limited results displayed on-line. For example, it does not supply figures that outnumber 100,000 articles (case of the USA and China annual production). However, in one specific case, the SCOPUS and ISI-Thomson Reuters databases results were compared.

In order to recover such results, 1996 was adopted as the initial year, for that is the beginning of the Scopus database operational year and because the Brazilian genome programs were launched in the end of this decade. Data compilation occurred in August, 2008.

The expression "RNA OR DNA OR (MOLECULAR BIOLOGY) OR PCR" was employed for the search of texts that had at least one of these key-words. This search strategy was defined due to the fact that it is extremely comprehensive when compared to a great number of alternative expressions that have been tested. The results were distributed according to their authors' origin, which was sub-divided into four country groups: Latin-American countries (Argentina, Brazil, Chile and Mexico), developed countries (Germany, United States, United Kingdom, Japan, France and Canada); Asian and African emerging countries (South Africa, China, South Korea and India); and East European countries (Poland, Hungary and the Czech Republic). Finally, the results related to the scientific production in molecular biology in each of these countries were compared to the total scientific production in order to find clues for the progress of molecular biology research in each country.

In order to assess the scientific production impact on technological innovation, the registration of patents at the American United States Patent and Trademark Office (USPTO) was used. The covered period was also from 1996 to 2007.

TOTAL SCIENTIFIC PRODUCTION GROWTH AND MOLECULAR BIOLOGY GROWTH IN BRAZIL, IN CONNECTION TO THE INTERNATIONAL SCIENTIFIC PRODUCTION (1996-2007)

Brazil in the Context of Latin-American Countries

Brazil occupies the leading position in the Latin-American context, where the scientific production growth rate in the period from 1996 to 2007 is considered. According to Table I, the Brazilian scientific production in this period increased 236%, followed by the production of Chile, Mexico and Argentina, which showed increases of 170%, 103% and 75%, respectively.

When the scientific production growth rate in molecular biology is analyzed, Brazil also holds the first place in the rank, with an even more dramatic increase of 434% in the 1996-2007 period, followed by Chile, Argentina and Mexico, with increases of 228%, 202% and 160%, respectively (Table II).

Brazil in Comparison with Developed Countries

When the Brazilian rate of growth of the scientific production is compared to developed countries rates in the period of 1996-2007, it is observed that Brazil remains holding the first position in the rank (Table III). As already shown in Table I, Brazil had an increase of

TABLE I
Growth of total scientific production in Brazil, Mexico, Argentina and Chile, on SCOPUS database (1996-2007).

Year	Brazil		Mexico		Argentina		Chile	
	Total	% Growth	Total	% Growth	Total	% Growth	Total	% Growth
1996	8,593	–	6,447	–	4,077	–	1,736	–
1997	10,289	19.74	6,915	7.26	4,603	12.90	1,866	7.49
1998	11,413	10.92	7,240	4.70	4,656	1.15	1,804	–3.32
1999	12.391	8.57	7,631	5.40	4,902	5.28	2,040	13.08
2000	13,388	8.05	7,713	1.07	5,212	6.32	2,034	–0.29
2001	13,698	2.32	7,901	2.44	5,211	–0.02	2,109	3.69
2002	15,804	15.37	8,538	8.06	5,514	5.81	2,528	19.87
2003	18,099	14.52	10,049	17.70	5,878	6.60	3,035	20.06
2004	20,252	11.90	11,272	12.17	6,019	2.40	3,285	8.24
2005	22,499	11.10	12,615	11.91	6,299	4.65	3,682	12.09
2006	27,376	21.68	13,630	8.05	6,894	9.45	4,504	22.32
2007	28,841	5.35	13,070	–4.11	7,150	3.71	4,684	4.00
Total	**202,643**		**113,021**		**66,415**		**33,307**	
% Growth 1996-2007		**236%**		**103%**		**75%**		**170%**

TABLE II
Growth of scientific production in molecular biology in Brazil, Mexico, Argentina and Chile, on SCOPUS database (1996-2007).

Year	Brazil		Mexico		Argentina		Chile	
	Molec. Biology	% Growth	Molec. Biology	% Growth	Molec. Biology	% Growth	Molec. Biology	% Growth
1996	361	–	303	–	197	–	82	–
1997	410	13.57	352	16.17	220	11.68	75	–8.54
1998	571	39.27	359	1.99	246	11.82	93	24.00
1999	653	14.36	387	7.80	231	–6.10	116	24.73
2000	763	16.85	430	11.11	293	26.84	121	4.31
2001	721	–5.50	457	6.28	352	20.14	131	8.26
2002	948	31.48	495	8.32	389	10.51	145	10.69
2003	1,203	26.90	649	31.11	456	17.22	202	39.31
2004	1,349	12.14	647	–0.31	464	1.75	228	12.87
2005	1,397	3.56	749	15.77	475	2.37	243	6.58
2006	1,749	25.20	778	3.87	545	14.74	257	5.76
2007	1,928	10.23	787	1.16	595	9.17	269	4.67
Total	**12,053**		**6,393**		**4,463**		**1,962**	
% Growth 1996-2007		**434%**		**160%**		**202%**		**228%**

236%, followed by Canada with 54%, United Kingdom with 42%, Germany with 38%, France with 35%, Japan with 16% and the United States with 12% (Table III).

In molecular biology, the Brazilian growth of 434% (Table II) is even more highlighted when compared to developed countries: Germany with 62%, Canada with 57%, United Kingdom with 40%, Japan with 35%, France with 27% and the United States with 20% (Table IV).

Brazil in the Scenery of Rapidly Developing Countries

Regarding the rapidly emerging countries, the total growth of China's scientific publications is the highest in the world. According to the SCOPUS database, its increase in the 1996-2007 period was of 583%, followed by South Korea, with 291%, Brazil with 236%, India with 115%, and South Africa with 71% (Table V).

TABLE III

Growth of total scientific production in Brazil and developed countries, on SCOPUS database (1996-2007).

Year	USA		Japan		United Kingdom		Germany		France		Canada		Brazil	
	Total	% Growth	Total	% Growth	Total	% Growth	Total	% Growth	Total	% Growth	Total	% Growth	Total	% Growth
1996	319,016	–	84,524	–	79,571	–	70,501	–	53,136	–	40,821	–	8,593	–
1997	313,570	–1.71	87,750	3.82	81,323	2.20	75,298	6.80	56,310	5.97	40,236	–1.43	10,289	19.74
1998	312,029	–0.49	88,498	0.85	83,512	2.69	77,970	3.55	57,326	1.80	39,321	–2.27	11,413	10.92
1999	309,249	–0.89	91,229	3.09	83,948	0.52	79,112	1.46	58,497	2.04	38,978	–0.87	12,391	8.57
2000	312,852	1.17	92,608	1.51	87,761	4.54	80,655	1.95	58,526	0.05	39,910	2.39	13,388	8.05
2001	308,681	–1.33	90,080	–2.73	83,195	–5.20	80,412	–0.30	56,881	–2.81	39,072	–2.10	13,698	2.32
2002	313,999	1.72	91,655	1.75	85,038	2.22	80,514	0.13	57,162	0.49	41,799	6.98	15,804	15.37
2003	334,011	6.37	98,597	7.57	94,450	11.07	90,633	12.57	63,655	11.36	48,641	16.37	18,099	14.52
2004	315,881	–5.43	102,534	3.99	98,157	3.92	94,479	4.24	67,060	5.35	53,427	9.84	20,252	11.90
2005	340,128	7.68	108,768	6.08	106,759	8.76	101,171	7.08	71,800	7.07	59,653	11.65	22,499	11.10
2006	355,850	4.62	107,313	–1.34	112,630	5.50	101,223	0.05	72,540	1.03	62,051	4.02	27,376	21.68
2007	355,985	0.04	98,244	–8.45	113,270	0.57	97,250	–3.92	72,048	–0.68	62,901	1.37	28,841	5.35
Total	**3,891,251**		**1,141,800**		**1,109,614**		**1,029,218**		**744,941**		**566,810**		**202,643**	
% Growth 1996-2007		**12%**		**16%**		**42%**		**38%**		**35%**		**54%**		**236%**

TABLE IV

Growth of scientific production in molecular biology in Brazil and developed countries, on SCOPUS database (1996-2007).

Year	USA		Japan		United Kingdom		Germany		France		Canada		Brazil	
	BM	% Growth	BM	% Growth	BM	% Growth	BM	% Growth	BM	% Growth	BM	% Growth	BM	% Growth
1996	30,138		7,954		5,791		5,472		4,701		3,070		361	
1997	28,742	–4.63	8,635	8.56	6,051	4.49	5,925	8.28	4,856	3.30	3,012	–1.89	410	13.57
1998	29,718	3.40	9,136	5.80	6,399	5.75	6,465	9.11	5,154	6.14	3,130	3.92	571	39.27
1999	29,451	–0.90	9,764	6.87	6,579	2.81	6,846	5.89	5,388	4.54	3,304	5.56	653	14.36
2000	30,495	3.54	10,152	3.97	6,936	5.43	7,050	2.98	5,422	0.63	3,234	–2.12	763	16.85
2001	31,502	3.30	10,278	1.24	6,830	–1.53	7.288	3.38	5,339	–1.53	3,278	1.36	721	–5.50
2002	31,743	0.77	10,337	0.57	6,770	–0.88	7.214	–1.02	5,320	–0.36	3,412	4.09	948	31.48
2003	34,987	10.22	11,232	8.66	7,814	15.42	8,303	15.10	6.148	15.56	4,029	18.08	1,203	26.90
2004	35,888	2.58	11,456	1.99	7,914	1.28	8,688	4.64	6,007	–2.29	4,330	7.47	1,349	12.14
2005	37,922	5.67	11,880	3.70	8,399	6.13	9,151	5.33	6,391	6.39	4,698	8.50	1,397	3.56
2006	37,198	–1.91	11,285	–5.01	8,219	–2.14	8,835	–3.45	5,982	–6.40	4,752	1.15	1,749	25.20
2007	36,202	–2.68	10,700	–5.18	8,100	–1.45	8,864	0.33	5,954	–0.47	4,828	1.60	1,928	10.23
Total	**393,986**		**122,809**		**85,802**		**90,101**		**66,662**		**45,077**		**12,053**	
% Growth 1996-2007		**20%**		**35%**		**40%**		**62%**		**27%**		**57%**		**434%**

Brazil holds the first place in previous ranks of scientific production, but here it falls to third place. At any rate, Chinese, South Korean and Brazilian predominance in science growth all over the world is evident.

If we compare the Brazilian scientific production in molecular biology to the production of developing countries, we may observe that Brazil holds the second place in the rank with a total of 434%, presenting lower results than China, which has reached an increase of 1243% (Table VI). South Korea is behind Brazil in this area, with 354%, followed by India with 324% and South Africa with 175%.

Brazil and East European Countries

When compared to East European countries, the Brazilian scientific production growth reached 236%, more than the double increase presented by the Czech Republic, with 93%. After it comes Poland with 74% and Hungary with 55% (Table VII).

In molecular biology, the difference between Brazil and East European countries decreased, but its production growth remains more expressive than the growth presented by Poland, the Czech Republic and Hungary (Table VIII).

TOTAL AND MOLECULAR BIOLOGY SCIENTIFIC PRODUCTION GROWTHS IN THE STATE OF SÃO PAULO (SCOPUS AND ISI DATABASES)

São Paulo was the pioneering state in genome projects through the ONSA program of FAPESP. A network was organized for this purpose, which encompassed over one hundred scientists from more than forty institutions of the São Paulo State (Simpson et al. 2000; Silva et al. 2002, Brazilian Genome Project Consortium et al. 2003). With the aim of focusing the state of São Paulo production, it was chosen to compare publication data from Scopus and ISI-Thomson Reuters databases in this case. Here, besides the expression "RNA OR DNA OR (MOLECULAR BIOLOGY) OR PCR", the origin (SÃO PAULO or SP and BRASIL or BRAZIL) was also considered in the searches.

In order to view all the data obtained in SCOPUS and ISI databases, the results were presented in charts placed side by side. As it has already been mentioned above, the non-use of the ISI database for studies with countries was due to the fact that the standard database available at the Internet does not allow for definition of figures that outnumber 100,000 (e.g., the USA and China annual production).

The scientific production evolution in the state of São Paulo recovered from the SCOPUS database showed an increase of 257% in the 1996-2007 period (Table IX). In the ISI database, the increase was of 218% (Table X). The increase of 257% was a little higher than the Brazilian increase (236%) in the same period (SCOPUS database, Table I).

In molecular biology, the scientific production in the state of São Paulo had expressive increases of 515% on the SCOPUS database (Table XI) and of 468% on the ISI database (Table XII). Therefore, the SCOPUS database reveals that, in this area, the São Paulo scientific production increase was 19% higher than the Brazilian one (Table II).

Table XIII provides a summary chart of the total scientific production and in molecular biology, comparing Brazil, the state of São Paulo and 16 selected countries. China, as we have already seen, has had an impressive increase of 1,243% in molecular biology in the 1996-2007 period. In 1995, China defined the Bio-Technology area as its priority number 1 in the National Plan for High Technology, among the 7 areas that had been selected as priorities (Zhangliang and Li-Jia 1997). Resources and efforts were higher than the ones from any other emerging country, and this fact may explain the great progress they reached in this area.

The Brazilian growth in molecular biology is also impressive (434%), reaching the second place among the countries in the present study. The state of São Paulo was highlighted in Table XIII due to its pioneering genome sequencing programs that have certainly influenced the advance of molecular biology, being higher than the Brazilian average (515%). It is difficult to find another explanation for the advances of molecular biology in Brazil and, more specifically, in the state of São Paulo.

It is interesting to mention that South Korea had a more modest growth in molecular biology in comparison to its total scientific production growth, with which it reaches the second place in the world. It is widely known that South Korea has presented an extraordinary

TABLE V
Growth of scientific production of Brazil and Asian and African emerging countries, on SCOPUS database (1996-2007).

Year	China		India		South Korea		Brazil		South Africa	
	Total	% Growth	Total	% Growth	Total	% Growth	Total	% Growth	Total	% Growth
1996	28,484	–	20,490	–	9,745	–	8,593	–	4,172	–
1997	31,236	9.66	21,058	2.77	11,933	22.45	10,289	19.74	4,237	1.56
1998	36,463	16.73	21,698	3.04	12,647	5.98	11,413	10.92	4,362	2.95
1999	37,632	3.21	22,846	5.29	14,665	15.96	12,391	8.57	4,514	3.48
2000	45,852	21.84	23,284	1.92	16,532	12.73	13,388	8.05	4,381	–2.95
2001	60,936	32.90	24,280	4.28	18,557	12.25	13,698	2.32	4,473	2.10
2002	62,256	2.17	25,990	7.04	19,651	5.90	15,804	15.37	4,980	11.33
2003	74,896	20.30	29,972	15.32	24,777	26.09	18,099	14.52	5,329	7.01
2004	111,274	48.57	32,311	7.80	29,126	17.55	20,252	11.90	5,899	10.70
2005	157,893	41.90	36,403	12.66	33,767	15.93	22,499	11.10	6,474	9.75
2006	181,041	14.66	40,981	12.58	37,324	10.53	27,376	21.68	7,152	10.47
2007	194,436	7.40	44,135	7.70	38,073	2.01	28,841	5.35	7,148	–0.06
Total	**1,022,399**		**343,448**		**266,797**		**202,643**		**63,121**	
% Growth 1996-2007		**583%**		**115%**		**291%**		**236%**		**71%**

TABLE VI
Growth of scientific production in molecular biology of Brazil and Asian and African developing countries, on SCOPUS database (1996-2007).

Year	China		India		South Korea		Brazil		South Africa	
	Molec. Biology	% Growth	Molec. Biology	% Growth	Molec. Biology	% Growth	Molec. Biology	% Growth	Molec. Biology	% Growth
1996	794	–	548	–	677	–	361	–	172	–
1997	994	25.19	563	2.74	766	13.15	410	13.57	189	9.88
1998	1,400	40.85	669	18.83	966	26.11	571	39.27	196	3.70
1999	1,795	28.21	692	3.44	1,070	10.77	653	14.36	212	8.16
2000	2,528	40.84	780	12.72	1,249	16.73	763	16.85	256	20.75
2001	3,168	25.32	941	20.64	1,436	14.97	721	–5.50	282	10.16
2002	4,116	29.92	1,097	16.58	1,550	7.94	948	31.48	291	3.19
2003	5,683	38.07	1,346	22.70	2,070	33.55	1,203	26.90	367	26.12
2004	7,336	29.09	1,528	13.52	2,336	12.85	1,349	12.14	367	0.00
2005	8,883	21.09	1,830	19.76	2,761	18.19	1,397	3.56	422	14.99
2006	9,979	12.34	2,125	16.12	2,927	6.01	1,749	25.20	471	11.61
2007	10,666	6.88	2,323	9.32	3,072	4.95	1,928	10.23	473	0.42
Total	**57,342**		**14,442**		**20,880**		**12,053**		**3,698**	
% Growth 1996-2007		**1243%**		**324%**		**354%**		**434%**		**175%**

impulse in technological innovation, holding the fourth place in the world in deposits of patents in the US Patent Office, only behind the USA, Japan and Germany. However, as opposed to China and Brazil, there was not any special effort in the molecular biology and bio-technology areas, and the investments were primordially aimed to the engineering, physics and chemistry areas.

It should be observed that for all countries the growth of molecular biology production has been higher than their total production, except in the United Kingdom and France. The average production of molecular biology increased the double regarding the total production in the 1996-2007 period (1.97 + 0.82, Table XIII). This time period coincides with genomes se-

TABLE VII
Growth of scientific production in Brazil and East European countries on SCOPUS database (1996-2007).

Year	Brazil		Poland		Czech Republic		Hungary	
	Total	% Growth	Total	% Growth	Total	% Growth	Total	% Growth
1996	8,593	–	11,300	–	4,866	–	4,222	–
1997	10,289	19.74	11,329	0.26	5,196	6.78	4,730	12.03
1998	11,413	10.92	11,588	2.29	5,259	1.21	5,096	7.74
1999	12,391	8.57	12,324	6.35	5,640	7.24	4,794	–5.93
2000	13,388	8.05	13,062	5.99	5,792	2.70	5,138	7.18
2001	13,698	2.32	13,784	5.53	6,204	7.11	4,808	–6.42
2002	15,804	15.37	15,037	9.09	6,474	4.35	5,049	5.01
2003	18,099	14.52	17,748	18.03	7,662	18.35	5,635	11.61
2004	20,252	11.90	19,416	9.40	8,235	7.48	5,937	5.36
2005	22,499	11.10	21,059	8.46	8,738	6.11	6,651	12.03
2006	27,376	21.68	22,258	5.69	9,812	12.29	6,761	1.65
2007	28,841	5.35	19,689	–11.54	9,402	–4.18	6,557	–3.02
Total	**202,643**		**188,594**		**83,280**		**65,378**	
% Growth 1996-2007	**236%**		**74%**		**93%**		**55%**	

TABLE VIII
Growth of scientific production in molecular biology – Brazil and East European countries; on SCOPUS database (1996-2007).

Year	Brazil		Poland		Czech Republic		Hungary	
	BM	% Growth	BM	% Growth	BM	% Growth	BM	% Growth
1996	361	–	318	–	247	–	187	–
1997	410	13.57	470	47.80	241	–2.43	249	33.16
1998	571	39.27	501	6.60	264	9.54	296	18.88
1999	653	14.36	593	18.36	303	14.77	313	5.74
2000	763	16.85	612	3.20	353	16.50	330	5.43
2001	721	–5.50	766	25.16	404	14.45	305	–7.58
2002	948	31.48	851	11.10	451	11.63	357	17.05
2003	1,203	26.90	1,055	23.97	565	25.28	466	30.53
2004	1,349	12.14	1,115	5.69	630	11.50	491	5.36
2005	1,397	3.56	1,238	11.03	623	–1.11	530	7.94
2006	1,749	25.20	1,316	6.30	720	15.57	554	4.53
2007	1,928	10.23	1,182	–10.18	764	6.11	563	1.62
Total	**12,053**		**10,017**		**5,565**		**4,641**	
% Growth 1996-2007	**434%**		**272%**		**209%**		**201%**	

quencing greatest efforts, including the human genome. This may be considered as a very important event towards this trend, once sequencings raised questions that opened a new world for the molecular biology: new genes, their functions, expressions (transcriptomic and proteomic techniques), cloning, and structure-function correlation in proteins, among others.

Sequencing projects in Brazil required a new scientific and organizational arrangement for their performance due to their characteristics (Harvey and McMeekin 2005). The large existing networks joined hundreds of researchers together and created a new version of science operation on a regional and national scale in Brazil.

TABLE IX
Growth of scientific production in the state of São Paulo on SCOPUS database (1996-2007).

Year	São Paulo Total	% Annual Growth
1996	3,209	–
1997	3,710	15.61
1998	4,083	10.05
1999	4,459	9.21
2000	4,703	5.47
2001	5,079	7.99
2002	5,848	15.14
2003	6,775	15.85
2004	7,534	11.20
2005	8,512	12.98
2006	10,342	21.50
2007	11,471	10.92
Total	**75,725**	
% Growth (1996-2007)		**257%**

TABLE X
Growth of scientific production in the state of São Paulo on ISI database (1996-2007).

Year	São Paulo Total	% Annual Growth
1996	3,717	–
1997	4,359	17.27
1998	5,004	14.80
1999	5,864	17.19
2000	6,173	5.27
2001	6,474	4.88
2002	7,750	19.71
2003	8,987	15.96
2004	9,302	3.51
2005	10,501	12.89
2006	10,580	0.75
2007	11,810	11.63
Total	**90,521**	
% Growth 1996-2007		**218%**

TABLE XI
Growth of scientific production in molecular biology in the state of São Paulo on SCOPUS database (1996-2007).

Year	São Paulo BM	% Annual Growth
1996	151	–
1997	180	19.21
1998	243	35.00
1999	275	13.17
2000	303	10.18
2001	317	4.62
2002	408	28.71
2003	509	24.75
2004	615	20.83
2005	639	3.90
2006	812	27.07
2007	929	14.41
Total	**5,381**	
% (Growth 1996-2007)		**515%**

TABLE XII
Growth of scientific production in molecular biology in the state of São Paulo on ISI database (1996-2007).

Year	São Paulo BM	% Annual Growth
1996	139	–
1997	191	37.41
1998	248	29.84
1999	288	16.13
2000	290	0.69
2001	339	16.90
2002	396	16.81
2003	496	25.25
2004	522	5.24
2005	577	10.54
2006	722	25.13
2007	789	9.28
Total	**4,997**	
% Growth 1996-2007		**468%**

PATENTS GROWTH ANALYSIS

It would be expected that the outstanding growth of Brazilian scientific production in molecular biology from 1996 to 2007 had been followed by an expressive increase in technological innovations in this field. This possible effect was investigated through an assessment to the number of patents registration at the United States Patent and Trademark Office (USPTO).

Patents Registration: Brazil in the Context of Latin-American Countries

Brazil appears in the second place in the Latin-American context of patents registrations, where the increase rate in the 1996-2007 period is considered (Table XIV). During this period, Chile had an increase of 1,540%, followed by Brazil with 365% of increase, Argentina

TABLE XIII
Growth of scientific production in molecular biology and total scientific production of countries and the state of São Paulo on SCOPUS database (1996-2007).

Geographical location	Growth (%) of production in molecular biology	Growth (%) of total production	Growth of production in molecular biology / Growth of total production
China	1.243	583	2.13
São Paulo State	515	257	2.04
Brazil	434	236	1.84
South Korea	354	291	1.22
India	324	115	2.82
Poland	272	74	3.67
Chile	228	170	1.34
Czech Republic	209	93	2.25
Hungary	201	55	3.66
Mexico	180	103	1.75
South Africa	175	71	2.47
Argentina	160	75	2.13
Germany	62	38	1.63
Canada	57	54	1.06
United Kingdom	40	42	0.95
Japan	35	16	2.19
France	27	36	0.75
USA	20	12	1.67

TABLE XIV
Growth of patent registration in Brazil and in Latin American countries (USPTO patent database, 1996-2007).

Year	Brazil		Argentina		Chile		Mexico	
	Total	% Growth	Total	% Growth	Total	% Growth	Total	% Growth
1996	93	–	36	–	5	–	369	–
1997	76	–18.28	36	0.00	8	60.00	360	–2.44
1998	114	50.00	54	50.00	22	175.00	557	54.72
1999	130	14.04	61	12.96	15	–31.82	541	–2.87
2000	134	3.08	72	18.03	16	6.67	554	2.40
2001	204	52.24	96	33.33	28	75.00	735	32.67
2002	301	47.55	140	45.83	41	46.43	1,023	39.18
2003	476	58.14	179	27.86	51	24.39	1,329	29.91
2004	508	6.72	196	9.50	74	45.10	1,368	2.93
2005	408	–19.69	154	–21.43	61	–17.57	1,196	–12.57
2006	553	35.54	188	22.08	70	14.75	1,553	29.85
2007	432	–21.88	166	–11.70	82	17.14	1,243	–19.96
Total	**3,429**		**1,378**		**473**		**10,828**	
% Growth 1996-2007		**365%**		**361%**		**1,540%**		**237%**

with 361% and Mexico with 237%. It is important to emphasize that what is being discussed is an increase in percentage, not in absolute numbers of patents. These results may be checked in Table XIV, where the Brazilian modest numbers may be observed at the USPTO patent database in the 1996-2007 period: the Brazilian number of patents is 3,429, whereas the Mexican one reaches 10,828.

When the growth rate in patents registration in molecular biology is analyzed Brazil is the leader, with an extremely expressive increase percentage of 3,700%, followed by Argentina with 900%, Mexico with 444%

TABLE XV
Growth of patent registration in molecular biology in Brazil and in Latin American countries (USPTO patent database, 1996-2007).

Year	Brazil		Argentina		Chile		Mexico	
	Molecular Biology	% Growth	Molecular Biology	% Growth	Molecular Biology	% Growth	Molecular Biology	% Growth
1996	1	–	3	–	0	–	16	–
1997	2	100.00	5	66.67	0	–	20	25.00
1998	4	100.00	6	20.00	0	–	44	120.00
1999	3	–25.00	3	–50.00	0	–	24	–45.45
2000	11	266.67	3	0.00	0	–	35	45.83
2001	7	–36.36	3	0.00	3	–	36	2.86
2002	18	157.14	2	–33.33	4	33.33	76	111.11
2003	42	133.33	11	450.00	9	125.00	100	31.58
2004	52	23.81	25	127.27	5	–44.44	114	14.00
2005	39	–25.00	14	–44.00	10	100.00	113	–0.88
2006	62	58.97	28	100.00	10	0.00	111	–1.77
2007	38	–38.71	30	7.14	13	30.00	87	–21.62
Total	**279**		**133**		**54**		**776**	
% Growth 1996-2007	**3,700%**		**900%**		**333%**		**444%**	

and Chile with 333% (Table XV). However, despite this increase, the number of patents (Table XV) is still of little significance, 279, less than half the Mexican amount, which is 776.

Patents Registration: Comparison Between Brazil and Developed Countries

Taking into account the period of 1996-2007 Brazil stands very weakly when compared to developed countries, as far as the number of patents is concerned. Its growth of 365%, followed by the developed countries that presented a growth rate within the range of 295%, is very low if the aspiration is to reverse the great difference that separates Brazil from these countries, concerning the number of patents that were recorded at USPTO (Table XVI).

Brazil's number of patents shows a more expressive growth in molecular biology when compared to developed countries (Table XVII). However, the same arguments prevail: the increase rate of patent records should have been much higher in order to diminish the great distance that separates Brazil from the developed countries.

Patent Registration: Brazil in the Setting of Rapidly Emerging Countries

The growth of the total of patents in China is higher than in any other country, including the developed countries. The Chinese growth was of 5,582%, followed by India with a growth of 3,760%, South Korea with 1,237%, Brazil with 365% and South Africa with 161% (Table XVIII).

When the molecular biology patent registration is compared in the same setting, Brazil appears in the third place, with a growth of 3,700%, higher than South Korea and South Africa (Table XIX). China and India have presented an overwhelming growth in the number of patent records in molecular biology of 5,275% and 4,540%, respectively.

Patent Registration: Brazil and East European Countries

The growth of patent registrations in the Czech Republic in all areas is 2,829%, the highest among East European countries (Table XX). It is followed by Hungary with 389%, Brazil 365% and Poland 349%. However, Table XX also shows that the number of patent registered is low in East European countries, even lower than in Brazil.

Brazil shows a higher position than East European countries concerning the registration of patent in molecular biology, appearing as the leader with a growth of 3,700%, followed by Hungary with 1,050%, Poland with 533% and the Czech Republic with 113% (Table XXI).

TABLE XVI
Growth of patent registration in Brazil and in developed countries (USPTO patent database, 1996-2007).

Year	USA		Japan		Germany		United Kingdom		Canada		France		Brazil	
	Total	% Growth	Total	% Growth	Total	% Growth	Total	% Growth	Total	% Growth	Total	% Growth	Total	% Growth
1996	73,377	–	24,743	–	7,786	–	3,189	–	2,991	–	3,377	–	93	–
1997	62,888	–14.29	20,112	–18.72	6,522	–16.23	2,902	–9.00	2,711	–9.36	2,975	–11.90	76	–18.28
1998	96,633	53.66	33,172	64.94	10,615	62.76	4,547	56.69	4,083	50.61	4,533	52.37	114	50.00
1999	94,843	–1.85	31,477	–5.11	10,300	–2.97	4,496	–1.12	4,170	2.13	4,398	–2.98	130	14.04
2000	99,039	4.42	32,622	3.64	11,668	13.28	4,817	7.14	4,611	10.58	4,756	8.14	134	3.08
2001	136,429	37.75	56,251	72.43	17,903	53.44	6,888	42.99	6,137	33.09	6,997	47.12	204	52.24
2002	202,521	48.44	75,854	34.85	24,327	35.88	9,770	41.84	9,107	48.39	9,109	30.18	301	47.55
2003	255,348	26.08	86,348	13.83	29,897	22.90	12,188	24.75	11,562	26.96	10,898	19.64	476	58.14
2004	259,163	1.49	92,799	7.47	33,450	11.88	13,628	11.81	12,295	6.34	12,280	12.68	508	6.72
2005	250,929	–3.18	88,022	–5.15	29,357	–12.24	12,231	–10.25	11,502	–6.45	10,815	–11.93	408	–19.69
2006	284,215	13.27	99,072	12.55	32,353	10.21	13,526	10.59	13,172	14.52	12,019	11.13	553	35.54
2007	247,179	–13.03	87,381	–11.80	29,016	–10.31	12,247	–9.46	11,827	–10.21	11,134	–7.36	432	–21.88
Total	**2,062,564**		**727,853**		**243,194**		**100,429**		**94,168**		**93,291**		**3,429**	
% Growth 1996-2007	**237%**		**253%**		**273%**		**284%**		**295%**		**230%**		**365%**	

TABLE XVII
Growth of patent registration in molecular biology in Brazil and in developed countries (USPTO patent database, 1996-2007).

Year	USA		Japan		Germany		United Kingdom		Canada		France		Brazil	
	Molec Biol	% Growth	Molec Biol	% Growth	Molec Biol	% Growth	Molec Biol	% Growth	Molec Biol	% Growth	Molec Biol	% Growth	Molec Biol	% Growth
1996	2,819	–	297	–	167	–	163	–	119	–	112	–	1	–
1997	3,515	24.69	274	–7.74	204	22.16	201	23.31	146	22.69	153	36.61	2	100.00
1998	5,982	70.18	564	105.84	346	69.61	371	84.58	268	83.56	238	55.56	4	100.00
1999	5,539	–7.41	468	–17.02	309	–10.69	401	8.09	276	2.99	250	5.04	3	–25.00
2000	5,470	–1.25	464	–0.85	330	6.80	380	–5.24	308	11.59	247	–1.20	11	266.67
2001	8,265	51.0	797	71.77	546	65.45	630	65.79	431	39.94	393	59.11	7	–36.36
2002	15,563	88.30	1,331	67.00	1,072	96.34	881	39.84	889	106.26	617	57.00	18	157.14
2003	23,112	48.51	2,001	50.34	1,647	53.64	1,335	51.53	1,197	34.65	970	57,21	42	133.33
2004	19,513	–15.57	2,338	16.84	1,859	12.87	1,438	7.72	1,136	–5.10	1,028	5.98	52	23.81
2005	19,107	–2.08	2,268	–2.99	1,623	–12.69	1,239	–13.84	1,109	–2.38	901	–12.35	39	–25.00
2006	19,816	3.71	2,814	24.07	1,763	8.63	1,416	14.29	1,146	3.34	1,000	10.99	62	58.97
2007	18,505	–6.62	2,518	–10.52	1,680	–4.71	1,331	–6.00	1,035	–9.69	981	–1.90	38	–38.71
Total	**147,206**		**16,134**		**11,546**		**9,786**		**8,060**		**6,890**		**279**	
% Growth 1996-2007	**556%**		**748%**		**906%**		**717%**		**770%**		**776%**		**3,700%**	

TABLE XVIII
Growth of patent registration in Brazil and in rapidly emerging countries (USPTO patent database, 1996-2007).

Year	China		India		South Korea		South-Africa		Brazil	
	Total	% Growth	Total	% Growth	Total	% Growth	Total	% Growth	Total	% Growth
1996	102	–	65	–	1,639	–	124	–	93	–
1997	113	10.78	62	–4.62	1,752	6.89	108	–12.90	76	–18.28
1998	185	63.72	133	114.52	3,523	101.08	147	36.11	114	50.00
1999	218	17.84	153	15.04	3,615	2.61	137	–6.80	130	14.04
2000	328	50.46	172	12.42	3,465	–4.15	139	1.46	134	3.08
2001	678	106.71	305	77.33	5,693	64.30	183	31.65	204	52.24
2002	1,247	83.92	728	138.69	8,853	55.51	234	27.87	301	47.55
2003	1,983	59.02	1,266	73.90	11,569	30.68	298	27.35	476	58.14
2004	2,885	45.49	1,597	26.15	15,348	32.6	396	32.89	508	6.72
2005	3,456	19.79	1,860	16.47	17,601	14.68	353	–10.86	408	–19.69
2006	5,012	45.02	2,262	21.61	22,974	30.53	365	3.40	553	35.54
2007	5,796	15.64	2,509	10.92	21,910	–4.63	324	–11.23	432	–21.88
Total	**22,003**		**11,112**		**117,942**		**2,808**		**3,429**	
% Growth 1996-2007	**5,582%**			**3,760%**		**1,237%**		**161%**		**365%**

TABLE XIX
Growth of patent registration in molecular biology in Brazil and rapidly emerging countries (USPTO patent database 1996-2007).

Year	China		India		South Korea		South-Africa		Brazil	
	Molec Biol	% Growth	Molec Biol	% Growth	Molec Biol	% Growth	Molec Biol	% Growth	Molec Biol	% Growth
1996	4	–	5	–	17	–	2	–	1	–
1997	7	75.00	7	40.00	24	41.18	1	–50.00	2	100.00
1998	12	71.43	20	185.71	32	33.33	1	0.00	4	100.00
1999	16	33.33	11	–45.00	39	21.88	2	100.00	3	–25.00
2000	10	–37.50	18	63.64	40	2.56	6	200.00	11	266.67
2001	30	200.00	33	83.33	80	100.00	6	0.00	7	–36.36
2002	57	90.00	100	203.03	132	65.00	11	83.33	18	157.14
2003	108	89.47	167	67.00	271	105.30	18	63.64	42	133.33
2004	170	57.41	126	–24.55	319	17.71	15	–16.67	52	23.81
2005	155	–8.82	160	26.98	365	14.42	7	–53.33	39	–25.00
2006	212	36.77	175	9.38	463	26.85	12	71.43	62	58.97
2007	215	1.42	232	32.57	439	–5.18	12	0.00	38	–38.71
Total	**996**		**1,054**		**2,221**		**93**		**279**	
% Growth 1996-2007	**5,275%**			**4,540%**		**2,482%**		**500%**		**3,700%**

Patent Registration: São Paulo in Comparison with Brazil

As opposed to what happens with the scientific production measured by publications, in which São Paulo State reached approximately 37% of the national production in the 1996-2007 period, according to the Scopus database (Tables I and IX), the total number of patents registered in the same period is lower in comparison with the national rate: 34% (Table XXII). Such unfavorable performance is surprising for a state with the most dynamic industrial sector in Brazil.

Such disequilibrium is even more surprising when the molecular biology area is focused. Whereas the scientific production of São Paulo State in molecular biology on SCOPUS database reaches approximately 44.6% of the national score (Tables II and XI), the deposit of patents on USPTO reaches only 23.7% (Table XXIII).

TABLE XX
Growth of patent registration in Brazil and in developing East European countries (USPTO patent database 1996-2007).

Year	Czech Republic		Hungary		Poland		Brazil	
	Total	% Growth	Total	% Growth	Total	% Growth	Total	% Growth
1996	7	–	54	–	47	–	93	–
1997	25	257.14	29	–46.30	25	–46.81	76	–18.28
1998	32	28.00	68	134.48	50	100.00	114	50
1999	36	12.50	47	–30.88	63	26.00	130	14.04
2000	63	75.00	53	12.77	38	–39.68	134	3.08
2001	52	–17.46	96	81.13	68	78.95	204	52.24
2002	104	100.00	143	48.96	106	55.88	301	47.55
2003	129	24.04	201	40.56	137	29.25	476	58.14
2004	157	21.71	251	24.88	196	43.07	508	6.72
2005	160	1.91	232	–7.57	234	19.39	408	–19.69
2006	155	–3.13	223	–3.88	252	7.69	553	35.54
2007	205	32.26	264	18.39	211	–16.27	432	–21.88
Total	**1,125**		**1,661**		**1,427**		**3,429**	
% Growth 1996-2007		**2,829%**		**389%**		**349%**		**365%**

TABLE XXI
Growth of patent registration in molecular biology in Brazil and in developing East European countries (USPTO patent database 1996-2007).

Year	Czech Republic		Hungary		Poland		Brazil	
	Molec Biol	% Growth	Molec Biol	% Growth	Molec Biol	% Growth	Molec Biol	% Growth
1996	–		2	–	3	–	1	–
1997	8	–	2	0	4	33.33	2	100
1998	6	–25.00	7	250	4	0.00	4	100
1999	6	0.00	8	14.29	8	100.00	3	–25
2000	4	–33.33	6	–25.00	1	–87.50	11	266.67
2001	8	100.00	11	83.33	8	700.00	7	–36.36
2002	11	37.50	13	18.18	12	50.00	18	157.14
2003	17	54.55	31	138.46	13	833	42	133.33
2004	19	11.76	27	–12.90	18	38.46	52	23.81
2005	18	–5.26	34	25.93	24	33.33	39	–25
2006	26	44.44	31	–8.82	22	–8.33	62	58.97
2007	17	–34.62	23	–25.81	19	–13.64	38	–38.71
Total	**140**		**195**		**136**		**279**	
% Growth 1996-2007		**113%**		**1,050%**		**533%**		**3,700%**

Patent Registration in Relation to Scientific Production

For most of the countries, the knowledge production (scientific publications) has a strong correlation with patents registration and with technological innovations (Acs et al. 2002). Despite a strong correlation between economic development and scientific and technological production has been shown (Ribeiro et al. 2006), there are strong cultural deviations concerning knowledge production and patents in different countries (Williams and McGuire 2001). The industrial sector participation in technological innovations is a feature of developed countries with relatively high per capita Gross National Product, although there may be exceptions to this rule (Guinet 2009). Table XXIV shows the correlation between patents and scientific production in the countries surveyed in this study, as well as in the state of São Paulo. It may be observed that under the ratio of 9 patent registrations per scientific publication there are 8 coun-

TABLE XXII
Growth of patent registration in São Paulo State in comparison with Brazil (USPTO patent database 1996-2007).

Year	São Paulo State		Brazil	
	Total	% Growth	Total	% Growth
1996	35	–	93	–
1997	32	–8.57	76	–18.28
1998	39	21.88	114	50.00
1999	40	2.56	130	14.04
2000	42	5.00	134	3.08
2001	59	40.48	204	52.24
2002	83	40.68	301	47.55
2003	175	110.84	476	58.14
2004	164	–6.29	508	6.72
2005	130	–20.73	408	–19.69
2006	196	50.77	553	35.54
2007	166	–15.31	432	–21.88
Total	**1161**		**3,429**	
% Growth 1996-2007	**374%**			**365%**

TABLE XXIII
Growth of patent registration in molecular biology in São Paulo State in comparison with Brazil (USPTO patent database 1996-2007).

Year	São Paulo State		Brazil	
	BM	% Growth	BM	% Growth
1996	0	–	1	–
1997	1	–	2	100.00
1998	0	–	4	100.00
1999	0	–	3	–25.00
2000	2	–	11	266.67
2001	1	–50.00	7	–36.36
2002	4	300.00	18	157.14
2003	8	100.00	42	133.33
2004	9	12.50	52	23.81
2005	11	22.22	39	–25.00
2006	21	90.91	62	58.97
2007	9	–56.14	38	–38.71
Total	**66**		**279**	
% Growth 1996-2007	**350%**			**3,700%**

tries and São Paulo State. Among these countries are: China, three Latin American countries including Brazil, three East European countries and South Africa. China may be considered an exception because, despite presenting a strong technological innovation profile, it had not been followed by a proportional growth in the number of patents. In fact, China adopted a bi-directionally alienated position for procedures of patents deposits, either by ignoring the respect for technologies that registered patents in foreign countries or by disdaining registrations of its own innovations. However, there have been great changes in China lately, with an explosion of patents registrations (Hu and Jefferson 2008) due to large external investments in the Chinese economy and consequent changes in intellectual property legislations. The period covered by the current research considers only part of such happenings in China, whose results should strongly influence this country position in the following years.

Mexico achieved a position closer to developed countries in the patents/scientific production correlation. The fact of being geographically close to the United States and also the presence of American industries producing innovations in Mexico certainly have weighted significantly in this context.

Positions are not meaningfully changed in the molecular biology area as shown in Table XXV. Japan was in the first position concerning patents registration normalized by scientific articles in overall fields of science, but it currently reaches the third position in the molecular biology area, being replaced by USA in the first position. India, which occupies the fourth position concerning all fields of sciences, falls down to the ninth position in molecular biology. Korea, with its recognized effort for technological innovation, changes from position 3 to 7 in Tables XXV. It is amazing that São Paulo State is so badly positioned in the area of molecular biology. In fact, some companies emerged in this state as a result of its own genome program with the perspective of innovation, mainly in the agricultural area. However, up to the moment, this has not been translated into a growth of patent registrations at USPTO.

FINAL CONSIDERATIONS

The imbalance between scientific production and technological innovation in Brazil has already been surveyed and discussed by other authors (see, for example, Zanotto 2002). One of the defended positions is that universities should have a more important role in innovation, occupying the room that has been relatively relegated to a second plan until now by the private sector (Galembeck 2007). The opposite position is that universities should dedicate themselves to the production of relevant scientific results, thus giving rise to the formation of high level human resources (Brito Cruz 2005). Fol-

TABLE XXIV
Scientific production according to the SCOPUS database and patent registration on USPTO database covering all fields of science and technology (1996-2007).

Geographic localization	Scientific production (SCOPUS)	Patents registrations USPTO	Patents registrations/ Scientific production (%)
Japan	1,141,800	727,853	63.75
USA	3,891,251	2,062,564	53.00
South Korea	266,797	117,942	44.21
India	343,448	11,112	32.35
Germany	1,029,218	243,194	23.63
Canada	566,810	94,168	16.61
France	744,941	93,291	12.52
Mexico	113,021	10,828	9.58
United Kingdom	1,109,614	100,429	9.05
South-Africa	6,121	2,808	4.45
Hungary	65,378	1,661	2.54
China	1,022,399	22,003	2.15
Argentina	66,415	1,378	2.07
Brazil	202.643	3,429	1,69
São Paulo State	75,725	1,161	1.53
Chile	33,307	473	1.42
Czech Republic	83,280	1,125	1.35
Poland	188,594	1,427	0.76

TABLE XXV
Scientific production according to the SCOPUS database and patent registration on USPTO database covering molecular biology (1996-2007).

Geographic localization	Scientific production (SCOPUS)	Patents registrations USPTO	Patents registrations/ Scientific production (%)
USA	393,986	147,206	37.36
Canada	45,077	8,060	17.88
Japan	122,809	16,134	13.14
Germany	90,101	11,546	12.81
United Kingdom	85,802	9,786	11.41
Mexico	6,393	776	11.19
South Korea	20,880	2,221	10.64
France	66,662	6,890	10.34
India	14,442	1,054	7.30
Hungary	4,641	195	4.20
Argentina	4,463	133	2.98
Chile	1,962	54	2.75
Czech Republic	5,565	140	2.52
South-Africa	3,698	93	2.51
Brazil	12,053	279	2.31
China	57,342	996	1.74
Poland	10,017	136	1.36
São Paulo State	5,381	66	1.23

lowing this point of view, it should be the private sector role to achieve advances in technological innovations. This is undoubtedly the prevailing model in developed countries.

The effort to have expression in specific areas generates positive results, as shown in the case of genomic programs. A wel-organized and well-conducted network, with realistic resources, allowed Brazil and the state of São Paulo to achieve a dramatic expansion in scientific publications, only subdued by China.

Such fact surely constitutes a necessary leap which, however, is not sufficient for a significant rise of the technological innovation process in the area of molecular biology.

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RESUMO

Vários programas de sequenciamento de genoma foram lançados no Brasil no final da década de noventa e início da década de 2000. As mais importantes iniciativas foram sustentadas pelo programa ONSA (http://watson.fapesp.br/onsa/Genoma3.htm) e visavam o domínio da tecnologia genômica e o progresso da biologia molecular para o estado da arte desta disciplina. Dois principais conjuntos de dados foram coletados no período de 1996-2007 para avaliar os resultados destes programas de genômica: a produção científica (bases de dados SCOPUS e o registro de patentes (US Patent and Trademark Office), ambos relacionados com o progresso de biologia molecular ao longo deste período. Em relação ao primeiro o Brasil de um grande passo em comparação a 17 outros países desenvolvidos e em desenvolvimento, sendo apenas superado pela China. Com relação ao registro de patentes na área de biologia molecular, o desempenho do Brasil fica bem atrás entre os países focados no presente estudo, confirmando a perdurável tendência de pobres conquistas em inovação tecnológica, quando comparado com produção científica. São discutidas as possíveis soluções para superar este desequilíbrio.

Palavras-chave: avaliação de ciência, genômica, cienciometria, biologia molecular.

REFERENCES

ACS CJ, ANSELIN L AND VARGA A. 2002. Patents and innovation counts as measures of regional production of new knowledge. Research Policy 31: 1069–1085.

BRAZILIAN GENOME PROJECT CONSORTIUM + 110 AUTHORS. 2003. The complete genome sequence of *Chromobacterium violaceum* reveals remarkable and exploitable bacterial adaptability. Proceedings of the Nationall Academy of Sciences 100: 11660–11665.

BRITO CRUZ CH. 2005. Reforma de estratégia. Folha de São Paulo, pág. 3, 22 de fevereiro.

GALEMBECK F. 2007. Jornal de Ciência, 10 de julho de 2007. http://www.jornaldaciencia.org.br/Detalhe.jsp?id=48604.

GUINET J. 2009. http://www.agencia.fapesp.br/materia/10936/busca-global.htm.

HARVEY M AND MCMEEKIN A. 2005. Brazilian genomics and bioinformatics: instituting new innovation pathways in a global context. Economy and Society 34: 634–658.

HU AG AND JEFFERSON GH. 2008. A great wall of patents: What is behind China's recent patent explosion? J Dev Econ 90: 57–68.

JUDSON HF. 1979. The eighth day of creation; makers of the revolution in biology. Simon and Schuster, New York.

PEREZ JF. 2002. Pesquisa: a construção de novos paradigmas. São Paulo Perspectiva 16: 30–35.

RIBEIRO LC, RUIZ RM, ALBUQUERQUE EM AND BERNARDES AT. 2006. Science in the Developing World: Running Twice as Fast? Computing in Science and Engineering 8: 81–87.

SILVA ACR, FERRO JA, REINACH FC + 62 AUTHORS. 2002. Comparison of the genomes of two *Xanthomonas* pathogens with different host specificities. Nature 417: 459–463.

SIMPSON AJG, REINACH FC, ARRUDA P + 113 AUTHORS. 2000. The genome sequence of the plant pathogen *Xylella fastidiosa*. Nature 406: 151–156.

WILLIAMS LK AND MCGUIRE SJJ. 2001. http://www.isnie.org/ISNIE05/Papers05/Williams_McGuire.PDF.

ZANOTTO ED. 2002. Scientific and technological development in Brazil. The widening gap. Scientometrics 55: 411–419.

ZHANGLIANG C AND LI-JIA Q. 1997. Plant molecular biology in China. Plant Molecular Biology Reporter 15: 273–277.