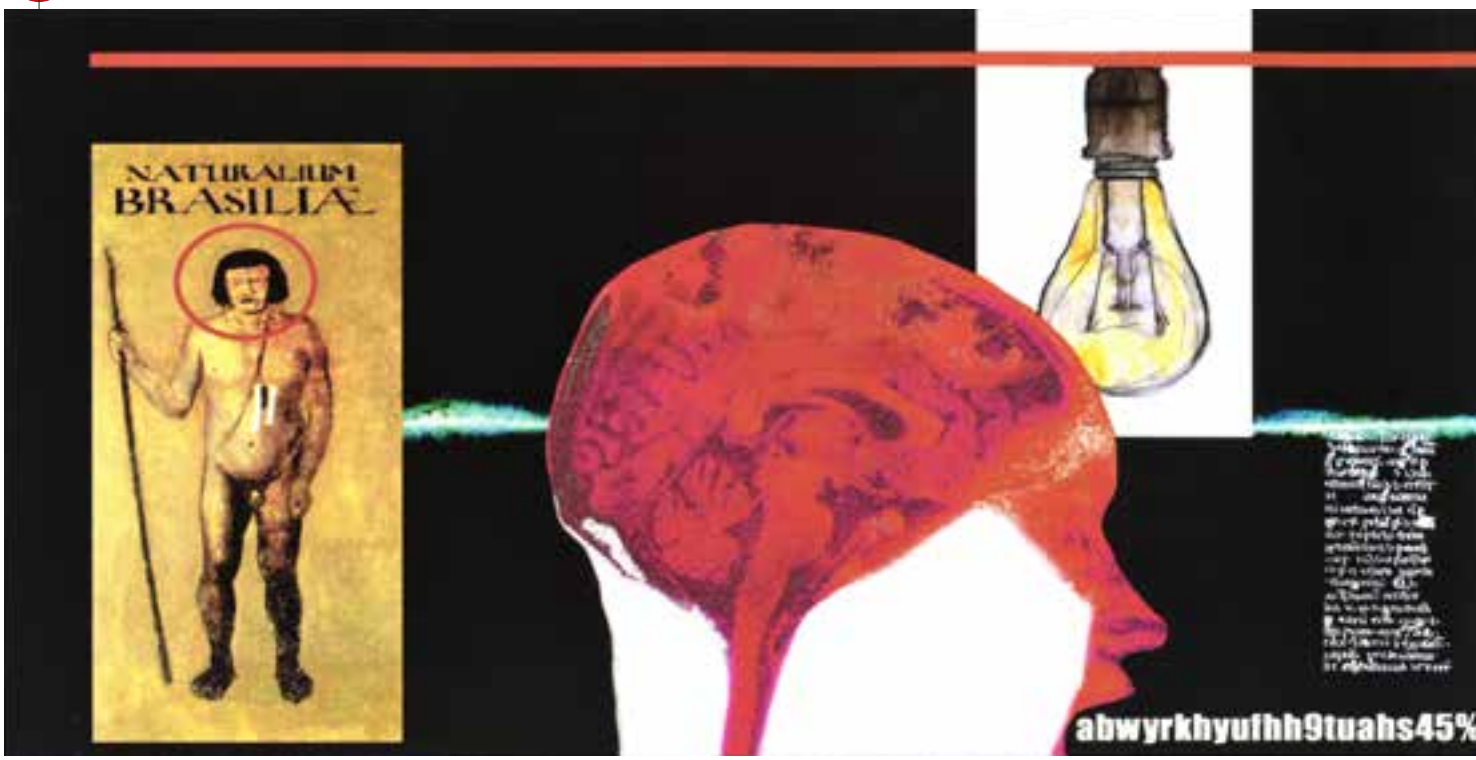

PERFORMANCE

The quantum leap of Brazilian science

National research goes professional, incorporating group work and improving its world ranking

MARCOS PIVETTA

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The small meeting was so informal that it even took place at home in the middle of diapers and feeding bottles. During her maternal leave of absence (she had just become a mother for the third time) the molecular biologist Marie-Anne Van Sluys, from the Biosciences Institute of the University of São Paulo (USP), then some thirty four years of age, wanted to enter into a new enterprise of FAPESP and would have liked to have been able to count upon the support of two colleagues from her unit: the experienced Carlos Menck, her husband, and the younger twenty- nine-year old Mariana de Oliveira. This was an enterprise that, back in the year 1997, nobody could have imagined would go well and would turn itself into a symbol of national science. Marie-Anne was going to present herself as a candidate to be the coordinator of one of the thirty laboratories that would attempt to carry out — and did carry out — the sequencing of the genome of the bacterium *Xylella fastidiosa* that brings about Citrus Variegated Chlorosis (CVC), a disease known by the orange growers as yellowing. This was a great responsibility for the daughter of a Belgian who was born in Rio de Janeiro and had written her doctorate thesis in France. After all, nobody in Brazil was at that time a specialist in genomics. "There was a hierarchy among the groups, but everyone was there to learn", Marie-Anne recalls well.

And learn they did. On July 13th of 2000, Marie-Anne was one of the 116 co-signers who made up the today historic scientific paper about the *Xylella* genome. The Brazilians were the first in the world to sequence the genome of a pathogen that attacks plants. For their feat they not only had their work reviewed in the English journal *Nature*, perhaps

ILLUSTRATION BY ELIZABETH TOGNATO

the most prestigious scientific publication, but were rewarded with the magazine's cover, an unprecedented distinction for national science. The *Xylella* genome generated enormous repercussions here and abroad, both within the scientific community and within society in general who do not live the day-to-day life of research laboratories. The realization set in and, perhaps somewhat grudgingly, the developed countries began to realize that the giant in South America had more versatility than they had previously thought. "Samba, football and... genomics?", wrote *The Economist*, the English magazine that specializes in economics, showing that the body swerve and the national reputation for dribbling had broadened out into a new field of knowledge.

By the way in which it was done, by the repercussions obtained and by the number of people involved in the project, the *Xylella* genome effectively provides a watershed for national science, in spite of many criticisms. The project served as a model for other initiatives of weight, such as the national network of the Brazilian Genome Program, established during 2000 by the National Council for Scientific and Technological Development (CNPq). The Brazilian Genome Program set up a network of twenty five laboratories, covering fifteen states, which broke the genetic coding of *Chromobacterium violaceum*, a bacterium of importance in biotechnology. But, looking back into the past, the most important news had nothing to do with sequencing or genes. The good news, really good news, is that over the past ten to fifteen years national science as a whole — and not simply that of genomics — has grown, has gained visibility and reached levels of international excellence never before seen. From 1990 until the present moment, the number of scientists at research institutions has tripled, the percentage of scientific articles published by Brazilians in indexed international magazines has doubled and the annual total of those getting doctorate degrees at Brazilian universities has increased five fold. "During this period, Brazilian research changed scale, gained critical mass and went professional", says Carlos Henrique de Brito Cruz, the rector at the State University of Campinas (Unicamp) and FAPESP's ex-President. The success of the national genome project was only the tip of the iceberg, which then began to emerge and today reveals itself entirely.

Innovation and wealth - For now, a leap equivalent to that of science has not happened in the so-called innovation sector, which should transform good ideas that come from research (basic) — generally done in public universities — into products, jobs and wealth for Brazil. One of the indicators used to measure the health of a country's technological research is to look at its evolution in the number of patents registered in the United States, the largest economy in the world. In 1990, Brazil obtained 41 patents of this type (South Korea 225). In 2001, the situation — unfortunately our own — has not radically changed: 110 new registrations for Brazil and 3,538 for the Asian tiger. It is true that the quantity of patents and registrations granted to residents in Brazil by the National Institute of Industrial Property (INPI), in Rio Janeiro, doubled between 1995 and 2002, going from 1,445 to 3,724 concessions. It's an heartening picture without being a revolution. "National companies still don't know how to innovate. It's a cultural question. This type of activity involves risks and de-

National research advances, but innovation is still skating on thin ice

Globalized Brazilian Science

One in every sixty five scientific articles that come out in indexed international journals is from Brazilians, proportionally double that of 1990

Year	% of Brazilian article in relation to the world	% of Brazilian articles in relation to L. America
1990	0.64	36.95
1991	0.69	38.39
1992	0.77	39.82
1993	0.75	37.90
1994	0.76	37.59
1995	0.83	38.01
1996	0.90	37.96
1997	1.00	38.19
1998	1.13	40.95
1999	1.25	41.59
2000	1.33	42.11
2001	1.44	43.06
2002	1.55	43.84

Source: Institute for Scientific Information (ISI)

Innovation is Growing Slowly

In 1990 the country registered 5.5 times fewerpatents in the USA than did South Korea. In 2001 the Orientals obtained 32 times more registrations than the Brazilians

Registrations conceded by the USA Patents Office

	Brazil	S. Korea
1990	41	225
1991	62	405
1992	40	538
1993	57	779
1994	60	943
1995	63	1,161
1996	63	1,493
1997	62	1,891
1998	74	3,259
1999	91	3,562
2000	98	3,314
2001	110	3,538

Source: US Patent and Trademark Office (USPTO)

GRAPHICS BY SIRIO J. B. CAN ADO

mands time", explained Sergio Rezende, the President of the Financier of Studies and Projects (Finep), the federal support agency for innovation.

In spite of the difficulties there has been progress in the sector, with the establishing in 1995 of the Partnership for Technological Innovation (PITE) program by FAPESP, which today serves as a model for similar initiatives in other states and within the federal environment. The PITE program promotes associations between research institutes in the State of São Paulo and companies of any size that are interested in developing products or productive processes with high technological content. It is hoped that the recent Innovation Law, sent by the federal government to the analysis by the National Congress, will be approved and open up the way for the effective transfer of knowledge from research centers to national companies. Another wager is that the money accrued by the sectorial funds, created in 1999 to develop innovation, begin to reach their destination. "To place the theme of innovation on the national agenda is fundamental for the country to maintain its economy competitiveness", says Carlos Américo Pacheco, from the Economy Institute of Unicamp and the ex-Secretary-Executive of the Ministry of Science and Technology (MCT). The theme could even have entered into official discussions, but industrial policy does not as yet reflect this. The force of Petrobras, Embraer and of the national agronomy business, thanks in part to the Brazilian Agricultural Research Corporation (Embrapa), is still the exception in the panorama of innovation.

Three times more articles - One of the most expressive indicators of the strengthening of national research is the increase in the number of papers signed by Brazilians in international magazines. In thirteen years the quantity of scientific articles written here and published in magazines indexed through the data base of the Institute for Scientific Information (ISI) tripled and the weight of national production doubled in relation to the rest of the world. During 1990, Brazilian researchers published 3,552 articles based on data from the ISI, which monitors the scientific production of 8,500 magazines covering twenty one areas of study. This number, followed up by the ISI, is equivalent to 0.64% of world production. During 2002, our national scientists published 11,285 pieces of work that corresponded to 1.55% of world production—more than, for example, the Brazilian participation in global trade (0.9%). The country has confirmed its position as the incontestable leader in science for Latin America. Almost 44% of the articles originating from this part of the planet today carry with them a Brazilian name. In 1990, this index stood at 37% (*see table above*). Do the ISI numbers faithfully reflect the quantitative and qualitative leap that has occurred with national science? They may not be the best possible parameter for this phenomenon, but, most certainly, they cannot be ignored. "Only 10% of the Brazilian scientific production finds its way into ISI magazines", says Evando Mirra, the President of the Management Center and Strategic Studies (CGEE), of the MCT.

"Nonetheless, this indicator is important, as it is accepted internationally and allows for making comparisons."

For example, it is possible to discover that today Brazil is the 17th producer of indexed scientific articles. One in every sixty five works published in the ISI based magazines carries the name of a national scientist. Twenty countries place more than 10,000 articles per year in indexed magazines — and Brazil is one of them. Of the countries that had published less than Brazil in 1981, only China and South Korea are now in a better position than our own. In 2002, China was the sixth producer of indexed articles (33,000 articles) and South Korea occupied the 14th position (15,000 articles). With respect to the growing process of globalization in science, the activity of research remains very well centralized on the richer countries. In spite of a fall in interest for pursuing a scientific career among its inhabitants, the United States still leads, by a long way, the list of countries with greater scientific production. The North Americans are responsible for 33.60% of the articles throughout the world indexed by the ISI. In second place comes Japan with 9.5%, which is then followed by the United Kingdom (9%), Germany (8.7%) and France (6.2%).

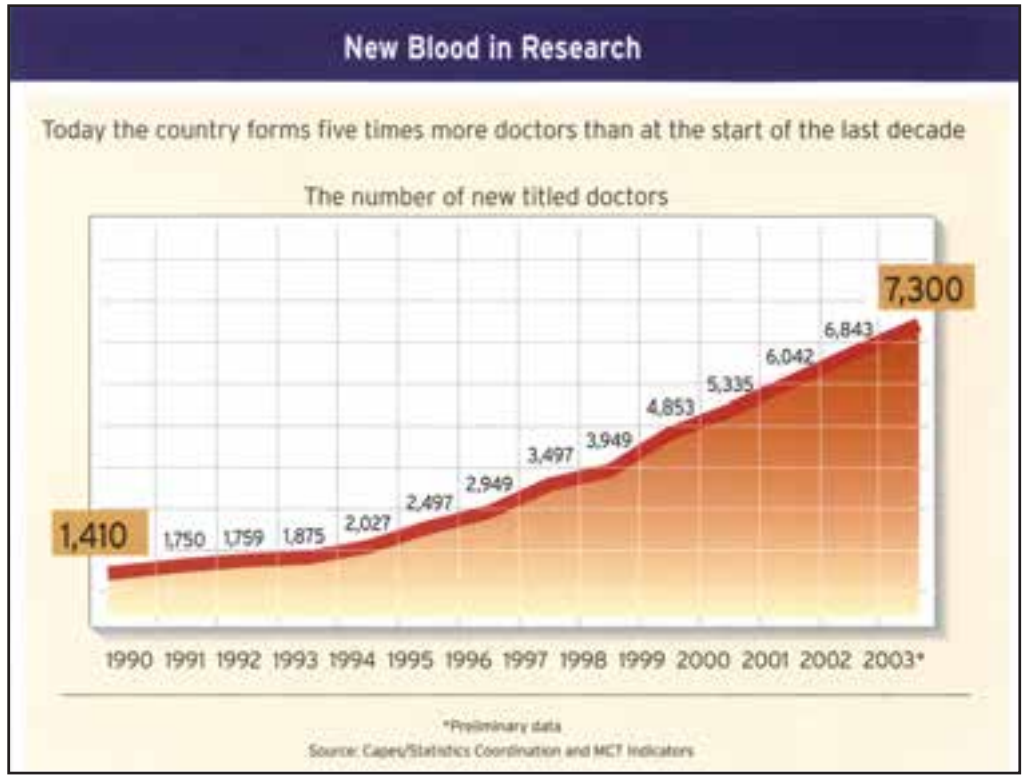
The ISI data also throws light on the areas of national science that are published abroad. Considering all of the indexed production between 1998 and 2002, the agrarian sciences lead this ranking. Their articles accounted for 2.96% of world production in this research area. Next came physics (2.12%), space science (1.92%), microbiology (1.91%), plant and animal sciences (1.87%), pharmacology (1.57%) and mathematics (1.51%). Whoever publishes more has more chance of being cited in works by colleagues, both here and abroad. More discretely than what occurs with the growth in the number of published scientific articles, the quantity of mentions of national work has also increased. Between 1992 and 1996, each Brazilian paper was cited on average 1.8 times. Between 1998 and 2002, this index had risen to around 2.0 citations per scientific article. Notwithstanding, in all of the study areas the Brazilian authors are still less cited than for the average world production. With 2.64 citations per published work, an index only 16% less than the world average, the area of psychology and psychiatry had the best performance in this field. Another parameter that shows Brazilians concern for publishing their work is the consolidation of the Scientific Electronic Library Online (SciELO). Funded by FAPESP since 1997, with the support of the Latin American and Caribbean Center on Health Science Information (Bireme), this electronic library today has a total count of 123 Brazilian journals, all openly accessible and free. Starting from 2002, the CNPq also began to invest in the SciELO.

Why has Brazilian science evolved so much over the last few years? The answer: it grew because there are more people involved — and above all more highly qualified people are carrying out research in the country. There was that fore mentioned increase to critical mass and the professionalization of research activities at the universities and study centers. Today the quantity of young people who are coming into the academic life with an eye on a scientific career has not stopped growing.

More women - In only nine years, from 1993 until 2002, the number of woman scientists working in universities and research centers tripled, according to data from the CNPq. The number jumped from a little above 20,000 to almost 60,000 of whom 60% have their doctorate degree (*see table below*). At these institutions 46% of the researchers are female. "But the presence of women as leaders in research groups is a little bit less, at around 41%", says Jacqueline Leta, from the Biomedical Sciences Institute of the Federal University of Rio de Janeiro (UFRJ), who carried out a study into female participation in national science. The group of researchers registered in the data base of the CNPq does not include scientists who work in private companies, possibly more than 30,000 individuals.

The increase in the number of people carrying out research has allowed national science to get involved in more ambitious projects, and in some areas, to in fact compete with the large international centers. "Up until the decade of the 1980s, the scientific community in Brazil was very small. It had a family style scheme of research production", comments Brito. "Everyone knew their colleagues in the area by name. This does not happen today." The words of the Unicamp rector, a student of the tendencies that permeate through national scientific production, should not be taken as a criticism of past generations. This has nothing to do with it. There were always highly qualified people carrying out top quality science in the country. It is just that the number of re-

searchers in the past was small. They formed themselves into a little club, restricted and closed. One couldn't have filled a football stadium with them. There were interactions between these few scientists but collaboration was essentially the fruit of a circle of friendly relationships and knowing the researcher personally—and not of projects or programs well thought out by the scientific community and development agencies. "There was fruitful collaboration between researchers. But now this cooperation is between institutions", says José Fernando Perez, FAPESP's Scientific Director. As well there was the maturing of research groups within the country. "They overcame the old vision of competition and moved on to one of more cooperation", comments Perez.



Responsible for close to 50% of the research produced in the country, the State of São Paulo was the pioneer in this new way of carrying out science, placing emphasis on larger and multidisciplinary projects that would stimulate teamwork in search of results of greater impact. Created in 1990, FAPESP's thematic projects are an example of national science that entered into adulthood and left adolescence behind. Until 2001, the Foundation has invested some R$ 230 million in 624 projects of all of the exact science areas, biology and humanities. Better organized and with more people, research has been able to embrace ambitious enterprises, such as the Biota program, a virtual institute without a fixed location that brings together some 500 scientists with the objective of surveying all of the São Paulo biodiversity. Also, it lead towards daring occurrences such as the policy/financing of joint ventures that allowed the entrance of Brazil into international enterprises and literally astronomy: the construction of the Southern Observatory for Astrophysics Research, the Soar, recently inaugurated in Chile. The observatory doesn't have a competitor on land — its competitor is in space, the Hubble telescope — and should give an impulse without precedent to national astrophysics. Of the total cost of the project, some US$ 28 million, the country contributed US$ 12 million and acquired the right to use 34% of the observatory's telescope that is mounted in the Andes.

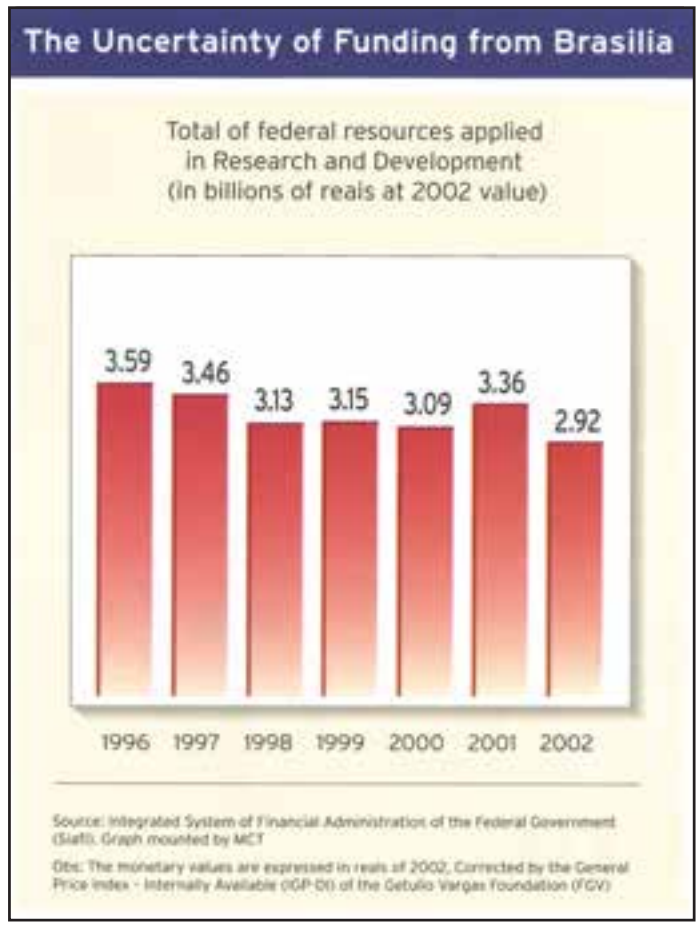
In the federal plan, there have also been recent initiatives that have stimulated multi-disciplinary and multi-centered work, bringing together complementary competences to investigate major themes in science, both basic and applied. The creation of the Millennium Institutes program in 2001 by the MCT/CNPq, comes within this context. These projects promote work within networks of a dispersed group of scientists, often in different institutions and states. Today there are seventeen Millennium Institute programs dedicated to themes as diverse as polymers, nanoscience, mathematics, cellular therapy, coastal resources and the genetics of citrus fruits. Another initiative coming from Brasilia that has excited Brazilian scientists was the launch during 1996 of the Support for Centers of Excellence Program (Pronex). "These two programs represent new methods of long term funding and are very good ideas", evaluates Luiz Davidovich, from the Physics Institute of the UFRJ and the coordinator of a Millennium Institute program concerning quantum information. "But they present problems in their implementation."

The discontinuity of funding - Problems in implementation is the polite manner of alluding to the chronic problem of the discontinuity of federal funding for science and technology. The country dedicates to this sector around 1% of the Gross Domestic Product (GNP), of which 60% comes from the public coffers (federal government and on a smaller scale, state governments) and 40% from business. Developed nations proportionally fork out double or triple this value into this sector. In Brazil private investment in research is still very low, but the situation has been worse. Some years ago, the spending from companies represented 10% of the total expenditure on science. "The goal is that we invest at least 2% of our GDP on research, with a greater participation coming from the private sector", says the medical doctor Eduardo Mo-

acyr Krieger, from the Heart Institute (Incor) of Sao Paulo, and President of the Brazilian Academy of Sciences (ABC). Due to the backing of FAPESP and to the trio of top class state universities (USP, Unicamp and Unesp), São Paulo is the privileged state on the national scenario. It feels less the oscillations on the size of the budget destined by central government to research (*see table concerning the evolution of federal funding for science over the last few years*).

In the other states, whose public system of science depends to a large extent on money from Brasilia and of the infrastructure existing at the federal universities, their vulnerability is greater and generates situations that are almost surrealistic "There are islands of excellence in a sea of misery", says Davidovich. "We have here at the UFRJ modern laboratories in buildings without lamps, with leaks and walls at risk of collapsing." To mitigate this picture, groups at the cutting edge of science from various Brazilian states are looking to establish partnerships with centers in better financial situations. "At the moments of crisis, the way out is to intensify cooperation with colleagues from Sao Paulo and abroad", says the neuroscientist Iván Izquierdo, from the Federal University of Rio Grande do Sul (UFRGS).

If there had not been an expressive increase — and permanent — in the volume of funding destined to national science, how can one explain the ascension of Brazilian research, recognized even abroad, starting in the years of the 90s? The answer is an open secret. Brazil continued with a State policy that began in the decade of the 1960s, and built up a postgraduate system, especially in the public universities. It was from the post-graduation that the yeast came that made the national research cake rise: the new doctorate graduates. Until the decade of the 1980s there was no alternative for many aspiring scientists who wanted to specialize in cutting edge areas of science the shortest way to a doctorate degree was via the airport. They managed to get a grant from some national development agency (or even from abroad) and take the plane with destination to the United States or Europe. Today this is no longer the case. "At my time one had to go abroad to specialize in plant molecular biology", recalls Marie-Anne Van Sluys. "Now it's possible to study for your doctorate here, learning the most modern techniques." Post-graduation courses have spread throughout the country. In 1990, the national programs of post-graduation formed 1,410 doctors. Last year close to 7,300 individuals received their doctorate degree on national territory (*see graph on page 22*).



The future of Brazilian science, and especially that of the technology and innovation sector, depends on the opportunities that will be created for this growing anchor of doctors, precious human capital. In the 21st century, few countries have the quantity of doctorate graduates that Brazil annually turns out. But what will be the destiny of this highly specialized workforce? At the national research centers there are not — and there could not be — vacancies for all of these scientist candidates. Even at that, a part of them will be absorbed at the universities, and if duly financed and stimulated, could boost our basic national research to one of excellence and weight. Inevitable some doctors will emigrate to the larger international research centers. And the others? The route for a good number of these young researchers must be private initiative, where they could solve two problems: one of a personal nature (get a job) and the other of a structural order for the country's economy (boost the sector of research and innovation in the business world).

At the end of last month, José Fernando Perez from FAPESP, and Fernando Reinach, from the Chemistry Institute of USP and President of Alellyx, the national biotechnology company, came up with a proposal to sponsor the marriage of new doctors with innovation: companies that contract doctors for carrying out the activities of Research and Development (R&D) would remain without the onus of all of the social taxes referring to the recruitment of these individuals. The incentive would be valid only during the first ten years subsequent to obtaining the title of doctor. The authors of the idea calculate that 50,000 new doctors could be benefited by this proposal over the next ten years. "The impact of this measure would be immediate", says Perez and Reinach. "The costs of hiring doctors would be reduced by 50%." For companies, one of the most expensive unrecoverable costs of a research department is the recruitment of brains. The proposed subsidy could generate a virtuous circle which Brazil needs so dearly: more jobs, more technology based companies, more private investment in postgraduates and a greater approximation between university and industry. National science has already made the jump. Now its time for innovation to follow suit. •