Ciência e Tecnologia no Brasil: Uma Nova Política para um Mundo Global

PHYSIOLOGICAL SCIENCES

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Summary

PHYSIOLOGICAL SCIENCES

Scope of this report

For the purposes of this report, the Physiological Sciences encompass the following disciplines: Physiology, Biochemistry, Biophysics, Pharmacology, Parasitology, Microbiology, Immunology and morphological sciences (Anatomy, Histology, Embryology), as well as Cell Biology, which pervades most of the other disciplines. Not included are the applications of physiological sciences in biotechnology, which are the subject of another report.

The survey of the state of the area in Brazil was made using the following sources:

(a) Annual reports and internal documents of the following granting agencies: Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq, National Council for Scientific and Technological Development); Coordenação de Aperfeiçoamento do Pessoal de Nivel Superior (CAPES, Coordinating Agency for Advanced Training of High Level Personnel); Financiadora de Estudos e Projetos (FINEP, Financing Agency for Studies and Projects); Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP, São Paulo State Research Foundation).

(b) Documents produced by past analyses and evaluations, such as the last evaluation of the national system of science and technology made by CNPq (1982) and the analysis of science and technology in the state of São Paulo made by FAPESP (1977), as well as documents issued by the Federal Government "Third Basic Plan for the Scientific and Technological Development" (SEPLAN, 1980) and the Congress (Covas and Passoni, 1992).

(c) Institutional reports and published papers with evaluations of the scientific productivity and of the performance of the graduate study programs.

(d) Annals of the meetings of the scientific societies and interviews with individual investigators. The following individuals were interviewed or provided information used in this report:

Renato Bailão Cordeiro, President, Brazilian Society of Pharmacology and Experimental Therapeutics;
A. Hasson-Volloch, President, Brazilian Biophysical Society;
L. Juliano, President of the Brazilian Biochemical Society;
Eduardo Katchburian, Professor of Histology, Escola Paulista de Medicina;
J. D. Lopes, President, Brazilian Society of Immunology;

Maria Marques, President, Brazilian Physiological Society;
Isac Roitman, President, Brazilian Society of Protozoology;
Wanderley de Souza, President, Brazilian Society of Electronic Microscopy;
Luis R. Trabulsi, President, Brazilian Society of Microbiology.

The data obtained from the different sources were sometimes fragmented, contradictory or outdated. It is particularly notewhorty the lack of dependable indicators of scientific activity in agencies such as CAPES and CNPq, which are constantly collecting the information but are apparently uncapable of processing and recording the large amount of data that have been collected throughout the years. From the information provided by these agencies, some effort and common sense were necessary to arrive at plausible figures, which however cannot be considered exact and should be subjected to revision when more reliable and updated data are made available by these agencies responsible for the promotion of science and education in Brazil.

Where is research in physiological sciences performed in Brazil

Historically, Brazilian research in the physiological sciences began in a few medical schools and public health institutes of Rio de Janeiro and São Paulo. Public health institutes, such as the Instituto Oswaldo Cruz in Rio, and the Instituto Butantan and Instituto Biologico in São Paulo, were, in the past, prominent centers for biomedical research, including in the physiological sciences. However, because of their much greater dependence on political fluctuations, they lost that position to the relatively more stable universities, which are responsible for the greater part of the scientific research being performed in the Country today.

As for the private sector, it has played a very minor role in promoting research in the physiological sciences in Brazil, since the local pharmaceutical industry imports most of their products and processes, with very little research and development being conducted locally. This is also true of the state-owned biotechnology institutes which produce immunobiologicals and other health-related products.

The lack of a good interaction between the academic and private sectors is a serious drawback for the development of a strong scientific establishment in the Country, and this occurs also in the area of the physiological sciences. The industries depend very little on the universities for the acquisition of know-how, and do not represent an important destination for the Masters and Doctors formed in the graduate schools. Typically, an industry seeks the university graduate to be trained in the routine tasks that it conducts locally, rather than the PhD who would be over-qualified for such tasks, and would require higher pay. As a result, job opportunities for PhD holders are rather limited to academic posts. This is an obstacle for the recruitment of the brightest students for post-graduate studies, and therefore negatively affects the quality of the scientific output of even the best research groups.

of the problems for the generation of a viable industrial research and establishment has been the lack of interaction between academic and the industries. This is due both to the lack commitment of the latter to research and development in this Country, and to the resistance of the universities this type of activity. A strict interpretation, by the universities, of the full time dedication their staff to teaching and research has hampered the use of their know-how outside the as consultants and advisors to private companies. This attitude, however, to be reversing, and a promising trend in some universities is the installation of for research and development projects linking the academic expertise with the sector. Notable examples of this trend, among others, are the University of

(CODETEC),
annex to the Chemistry Institute of the University of São Paulo.

segment where research in physiological sciences should be increased, that of government public health institutes. These institutions have for a long time

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Fundação
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careers for their scientific staffs.

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1.5%
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presently
This situation might be improved if
Government
to
discussed in the national Congress are promising steps
law,
income

"manufactured product tax" (IPI, Imposto sobre Produtos Industrializados) from equipment acquired for that purpose. Another promising step in the direction of development of private research and development programs in Brazil is the law for the protection of intelectual and industrial property.

The main sources of support for basic science and technological development in Brazil are the federal institutions CNPq and FINEP, of the Ministry of Science and Technology, and CAPES, of the Ministry of Education. Several states also have agencies for the support of science and technology, but the only one of these with a significant contribution to research in the past is the São Paulo state's FAPESP. Another significant source of money for research is the "Programa de Apoio à Ciência e Tecnologia" (PADCT), with resources from the World Bank and from the Brazilian Government which are administered by FINEP, CNPq and CAPES.

The support given by these different sources to biological sciences in 1991 is shown in Table I. Although these numbers refer to all the biological sciences (including genetics, zoology, botany and ecology), the support given to the physiological sciences may be approximated by considering that these sciences historically receive about 60% of the expenditures of the CNPq in the biological area.

It is noteworthy that FAPESP, which grants funds only to institutions in São Paulo state, appears as the most important source of money for research projects, contributing with 41% of the total amount granted in 1991. This is due, in part, to a decrease in the federal support for science that occurred since 1989, reaching alarming proportions in 1991 and 1992, when support of new grants by CNPq was practically non-existent, expenditures being restricted to fellowships and to grants contracted in the previous year. Table II shows that, with the exception of the increase in the amount of CNPq support for research grants in 1992, the funding for research projects by that agency has been decreasing since 1987. As for FINEP, a trend for increasing its annual support for research projects in the period 1987 - 1989 was sharply reversed since 1990. Thus, both federal agencies were greatly affected by the economic and political crisis suffered by the Country during these years. Unless this negative trend in support for science is quickly reversed, irreparable damage may be suffered by research groups and institutions that took many years to reach a reasonably productive stage.

It must also be pointed out that the low level of support to scientific research by the federal agencies is aggravated by the dispersion of the available resources by numerous groups and individuals without rigid criteria as to the merits and viability of the projects. Another important shortcoming, which applies particularly to the CNPq, is the lack of adequate evaluation of the performance of the projects that receive support by the agency. These practices allow the funding of numerous projects without merit, and the survival of groups that have presented mediocre or insignificant performances for years, at the expense of insufficient support for the most productive research groups.

The
and
project evaluation that should be emulated by the federal agencies.

the resources has been
concentration of its resources in
most viable projects and productive groups, and is committed to play an important role

However,
expenditures
lack
obligations to the program.

participation of the physiological sciences in the PADCT is limited to those that may be included in one of the sub-programs, namely Biotechnology. In this emphasis is placed on supporting projects linking academic research in the to the development of products by the industry, but part or the resources are to basic research. This has allowed the survival of a few prominently productive which, in spite of the irregular supply of the funds for local expenditures (which on funds provided by the Brazilian government), have been favoured by the

Work force

number of active scientists in the physiological sciences may be appraised by

scientific societies.

involved in any of the sub-areas is the number
ordinary (effective) members in the respective scientific societies. A list of these is given below, with the respective number of members (excluding student

Biophysics

Biochemistry

Immunology

Microbiology

Sociedade Brasileira de Virologia: 59

Morphology

Sociedade Brasileira de Anatomia: 600
Sociedade Brasileira de Microscopia Eletrônica: 481
Sociedade Brasileira de Biologia Celular: 72

Parasitology

Sociedade Brasileira de Protozoologia: 220

Pharmacology

Sociedade Brasileira de Farmacologia e Terapêutica Experimental: 428

Physiology

Sociedade Brasileira de Fisiologia: 540

These numbers refer to the ordinary members at the end of 1992, with a small degree of uncertainty because some of the societies are not able to precise the actual number of full paying members at a certain point in time. Also, it must be pointed out that some individuals belong to more than one society, leading to an overestimate of the total number of investigators belonging to all societies. Nevertheless, the above numbers give a good idea of the contingent of people working in each discipline.

Of the 3849 members of the above listed societies, who supposedly are engaged to a greater or lesser degree in one of the physiological sciences, the number of those more qualified is given by the holders of Doctor's degrees. Table III shows that, in 1992, about 50% of the members of the physiological societies (1946) held PhD degrees. Here again, the division between the disciplines is in some cases artificial, but the numbers give an approximate idea of the relative weight of their contribution to research in the physiological sciences in Brazil.

Another indicator, which reflects the number of the more productive investigators, is the number of holders of CNPq's career Fellowships ("bolsas de pesquisador"). These are scientists classified by a committee of their peers into the categories of "Pesquisador I" (senior or independent researchers), and "Pesquisador II" (holding at least a Doctor's degree and publishing regularly in refereed journals). An idea of the selectivity of these two categories is given by the fact that, of the total of 1946 scientists holding Doctor's degrees, 734 (38%) have Pesquisador I or Pesquisador II fellowships (Table III).

Besides the Pesquisador I and II fellowships, the CNPq also awards "special fellowships" (post-doctoral, regional development fellowships, associate investigators, fellowships for retired individuals continuing research, visiting investigators and recent-doctors). These categories, however, contribute little to the total number of investigators supported by CNPq fellowships, amounting, in 1992, to only 56 (7.1%) out of a total of 790 career fellowships granted to the physiological sciences.

As for the Departments where research in physiological sciences is being conducted, an estimate of the active groups may be obtained from the data available from

CAPES regarding the accredited graduate courses in that area. Because of the structure of scientific organization and funding in Brazil, most of the research in any discipline is being conducted in university departments that host graduate courses accredited by the Federal Education Council (Conselho Federal de Educação). Only these departments are able to obtain fellowships for the graduate students, which constitute the major part of the scientific labor force in this Country (post-doctoral Fellows are a negligible part of that labor force). Therefore, these departments conduct practically all of the research being done at a competitive level, and also receive most of the research grants made available by Federal and State funding agencies. Table IV shows the number of accredited graduate courses in the different disciplines, at the end of 1992.

Regional distribution

Research in the physiological sciences, as is also the case in other scientific areas, is heavily concentrated in the State of São Paulo (chiefly in São Paulo, Campinas and Ribeirão Preto) and the cities of Rio de Janeiro and Belo Horizonte, although in certain disciplines there are active groups in other cities, such as Curitiba, Porto Alegre and Florianópolis in the South, Recife and Fortaleza in the North-East, and Brasilia in the Central region.

An idea of the regional distribution of the Brazilian scientific community doing research in the physiological sciences may be obtained from Table IV, showing the number of accredited graduate courses in the five regions of the Country. Of the total of 55 courses, 40 (73%) are in the South-East, and only 27% are in the other four regions.

The regional imbalance is even more evident in the fact that, of the 30 courses accredited to award the highest degree (Doctorate), 27 (90%) are in the South-East and only 10% are in the other four regions. The grades given to the graduate courses by CAPES, also reflect the regional imbalance. Of the courses evaluated in 1991, 90% of those of the South-East were graded A or B, whereas only 60% of those of the remaining regions received A or B.

The distortions in the regional distribution of scientific research groups have been the subject of a long-standing discussion, and some actions to overcome this problem have been taken by the CNPq, where a program of "regional scientific development" has been carried out for many years. Within this program, special criteria were adopted for granting aid to scientific projects coming from the less developed regions. Although an objective evaluation of the results of this program is not available, the continuing stagnation of the scientific productivity in the best physiological sciences departments in these regions suggest that other types of action should be taken to improve the conditions and the efficiency of the efforts of local groups to conduct scientific research.

For many years, one such action was the policy by which CNPq and CAPES give

priority for fellowships to students from less developed areas in Brazil to pursue their graduate studies abroad. This is reflected by the large proportion of PhD holders which is now found in the staffs of physiological sciences Departments of north-eastern universities. Thus, for example, 71% of the Doctor's degrees of the staff in the Department of Biochemistry of the Federal University of Ceará were obtained abroad, and so were 90% of those in the Department of Biochemistry of the University of Pernambuco. In contrast, the percentage of the staff that obtained their Doctor's degrees abroad is only 5% in the two most productive Departments of Biochemistry in the Country, namely those of the University of São Paulo, and of the Biology Institute of the Federal University of Rio de Janeiro. Apparently, the scientific productivity of these Departments is inversely proportional to the proportion of their staffs holding Doctor's degrees from foreign universities.

Experience has shown that, after an average of 4 years graduate training abroad, the students from less developed areas have serious problems to adapt to the working conditions of their home universities, where they find an environment not propitious for scientific research (De Meis and Longo, 1990). This is also true, to a lesser degree, in the case of individuals that obtain their doctorates in more developed universities of the south-eastern region.

Better results appear to be obtained when graduate students follow a program in which at least part of their thesis work and courses are done in their local universities, with supervisors and visiting professors from more established graduate courses in the south-eastern universities. An interesting experiment is the establishment of official co-operative programs between universities of the different regions to allow students of the less developed areas to conduct part of their graduate training in their local universities. Examples of such programs are those involving the Departments of Psychobiology and of Biochemistry of the Escola Paulista de Medicina (EPM), in São Paulo, and the Departments of Physiology and of Biochemistry of the Federal University of Rio Grande do Norte (UFRN). Such programs have given good results in setting up new research groups where none existed before but have also met with many difficulties, and have shown that at least ten years of intensive effort are needed for fostering groups with an autonomous scientific research program in less developed universities (Carlini, 1980; Moreira, 1991).

The most serious problem in the development of these new groups is the generation of scientific leadership, which is a long-term process. A strategy to circumvent this problem is the importation of scientific leadership from other universities. Very successful examples of this strategy occurred in the Department of Biochemistry of the Federal University of Rio Grande do Sul and in the Department of Pharmacology of the University of Santa Catarina.

Another approach to generate qualified groups in less developed areas is illustrated by the Laboratório de Imunopatologia Keijo Azami (LIKA), in Recife, in which a massive

from the Japan International Cooperation Agency (JICA) was used to create institute where japanese scientists worked with the local staff to install laboratories with equipment and research projects aimed at locally relevant problems. After a period which the japanese endeavoured to create a self-sustained institute, LIKA is now trying proceed independently with its activities. An objective analysis of this interesting venture its performance after becoming independent of

Scientific productivity

indicators of the quantitative scientific productivity of the different disciplines the physiological sciences, in Brazil, are given in Table V. The ratio of 3.8 between the of abstracts presented at annual meetings and the number of full papers published indexed journals reflects the practice of fragmenting the research presented at the meetings to give each collaborator of the research the opportunity to present a poster.

When the total number of papers published in indexed journals published in Brazil and abroad (749) is divided by the number of holders of Doctor's degrees (1046, from Table III), an index of 0.4 papers per person per year is obtained.

Unfortunately, a qualitative analysis of the scientific productivity in all the disciplines of the physiological sciences is not available. Only in the discipline of Biochemistry scientometric analyses have been effectively employed in attempts to evaluate the qualitative performance of the area (see below).

Personnel training

The great majority of the qualified personnel added to the physiological sciences community each year comes from the accredited graduate courses referred to in Table IV. An idea of the annual output of this system is given by the number of students enrolled in these courses and the number of Master's and Doctor's degrees awarded in 1991. Table VI shows that 281 new Master's degrees were generated from a population of 1,235 registered students. This proportion of 23% is in line with the information provided by CAPES that the average time taken to obtain the Master's degree is about 4 years. For the Doctor's degree, the output in 1991 was 133, out of a population of 898 students, indicating an average of more than 6 years for the attainment of that Degree.

Graduate studies abroad are responsible for a smaller part of the degrees obtained by Brazilian scientists. Nevertheless, this segment has been incentivated in recent years, with a commitment of the federal agencies (CAPES, CNPq) to maintain a contingent of about 5,000 fellows abroad, at an annual cost of 150 million dollars. Theoretically, about 150 of these fellows should be returning to Brazil with their degrees every year.

In the physiological sciences, Table VII shows that, in 1992, 28 students were working abroad for the MS and 92 for the PhD degree, with fellowships from CNPq and CAPES. The only other agency giving significant, although much smaller, support for graduate studies abroad is the São Paulo State Research Foundation (FAPESP), which, during the period 1987-91 granted 10 fellowships in the area of biological sciences for that purpose.

In the physiological sciences, the number of MS students abroad has drastically diminished during recent years, as the CNPq's Advisory Committees in these areas tend to eliminate this type of fellowship, in recognition of the fact that much better returns are obtained by investing in more mature students for training abroad. In this regard, the avowed priority of the agencies is the post-doctoral training, followed by the PhD fellowships. Nevertheless, when the number of post-doctoral fellowships granted by federal (CNPq, CAPES) and state agencies (FAPESP) is compared with the number of Doctor's degrees granted by Brazilian universities in a two-year period (average duration of a post-doctoral fellowship), only about 25% of the individuals with these degrees are going abroad for post-doctoral work. Furthermore, the number of foreign PhD fellowships granted by the federal agencies (CNPq and CAPES) still exceeds those of post-doctoral fellowships abroad. In contrast, the São Paulo State Research Foundation clearly favours post-doctoral fellowships over PhD studies: in the period 1987-91, 80 foreign post-doctoral fellowships were granted by FAPESP, as compared to 10 fellowships for the obtainment of PhD degrees abroad, in the biological sciences.

Mention should be made that an increasing number of the fellowships granted by CNPq and CAPES for graduate studies abroad, at the PhD level, are "sandwich fellowships", in which the student is enrolled in a graduate course in a Brazilian university and pursues part of his thesis work overseas, working on a project in which there is supposed to be a collaboration between his supervisor in Brazil and his host abroad. The "sandwich fellowship" program has the following advantages over the "full PhD" fellowships: (a) during his studies abroad the student maintains his ties with a Brazilian co-supervisor and fulfils part of his thesis and course requirements in the Brazilian institution which will be responsible for awarding him his degree; (b) the requirement for a joint project between the Brazilian supervisor and a foreign colleague promotes opportunities for international collaboration that may benefit the supervisor's research; (c) the student is maintained abroad for a much shorter time than in a "full PhD" fellowship, with obvious economy of the scarce resources available.

A retrospective analysis of the scientific productivity (based on number of papers and impact of the journals) of age-matched groups of scientists that had obtained their PhD's abroad or in Brazil gave some interesting results (De Meis and Longo, 1990). The performance of scientists that obtained their degree in Brazil and never had formal training abroad was essentially the same as that of biochemists that had obtained their degrees in Brazil, and the publications produced in the course of their PhD work did not differ in

number or impact. The authors conclude that, while post-doctoral training overseas is effective in improving the scientific productivity of Brazilian biochemists, no advantage is gained from sending them abroad to obtain their PhD. On the other hand, the average cost for a Brazilian student to obtain a PhD degree in Biochemistry is about four times more expensive abroad than in Brazil.

The scientific community in Brazil is very small, when compared to that of developed countries, and the training of new personnel is well below the needs of the area, in terms of the establishment of a vigorous and stable community. As an example, in 1985 there were 1.2 PhD and 3.0 MS degrees in the life sciences awarded per million inhabitants in Brazil (data from CAPES), whereas in the United States of America there were 25 PhD and 40 MS degrees awarded per million inhabitants (National Science Foundation, 1987). Obviously, a vigorous scientific community in the physiological sciences cannot be attained in Brazil without a substantial increase in the number of qualified scientists produced by the graduate courses. However, there are several factors limiting the growth of the system, some of which are discussed below.

(a) Shortage of thesis supervisors

The number of qualified thesis supervisors in the accredited courses in physiological sciences is estimated to be ca. 600. Taking into account the total number of students shown in Table I, this indicates that, on the average, each supervisor has 2.0 MS students and 1.5 PhD students under his supervision. This suggests that the system is working at nearly full capacity, since the ideal average number of graduate students per supervisor is generally thought to be 3.

This problem is aggravated by the Brazilian civil service rules that allow early retirement of university professors with full pay, with two adverse results: the system looses professors that are in their fifties, at the height of their scientific productivity, and a large proportion of the universities' payroll is devoted to payment of inactive personnel (estimated to reach about 40% of the payroll in the University of São Paulo within the next two years). Some universities have adopted the policy of allowing their most qualified retired professors to be hired again, as full or associate professors. However, although they do not occupy the same positions from which they had retired, this practice is viewed with reserve by many who fear that, even when judiciously applied, it may be an incentive for early retirement of qualified personnel, and if abused, it may allow re-hiring of less qualified people, who will occupy positions that are much needed for adding competent younger scientists to the system.

In an attempt to alleviate this problem CAPES has established a program to delay the retirement of scientists who have age for retirement, but whose contributions to their highly rated graduate courses are considered important. In this program, significant fellowships are provided as long as the scientist does not retire, and remains productive. Here, again, the danger is the possibility of abuses, resulting in the occupancy, by

scientists no longer productive, of posts that should be made available to the new generation if retirement of these individuals were encouraged. An alternative that does not have this drawback is the "retired investigator" fellowship program that has been effective for several years in the CNPq. This program allows retired scientists who are still active and productive, to continue their research and to contribute to the training of new scientists. These fellowships appear to be a better way of using the work of senior scientists, and should be made more attractive, by matching their values to those of the CAPES program and by including some insurance of continuity of the support (with protection against inflation) as long as the performance of the awardee justifies it.

The shortage of competent thesis supervisors is a difficult problem to overcome because the formation of mature and competent scientists should include at least 2 years post-doctoral work (preferably abroad), meaning at least 8 years of post-graduate training. A possible strategy to overcome this problem would be to import qualified scientists.

De Meis and Longo (1990) have estimated that bringing from abroad and maintaining a scientist with qualifications at least as good as those of the best thesis supervisors now available in this Country would cost about the same as sending two graduate students overseas to obtain a PhD degree. These authors comment that with the resources used by CAPES and CNPq to send 5,500 graduate students overseas (in all areas of knowledge) it would be possible to import 2,250 competent scientists. A major difficulty resides in recruiting scientists at the peak of their careers to be settled in an underdeveloped country. However, this might be circumvented by selecting senior scientists approaching retirement, or seeking qualified personnel in countries with other problems, such as those of Eastern Europe. These possibilities are often discussed by the granting agencies, but no serious effort has been made to bring a significant number of foreign scientists and to give them minimum conditions for conducting their research in their new environments.

(b) Low efficiency of the graduate courses

The long time taken to train a graduate student is detrimental for the efficiency of the system: it takes ca. 4 years to produce an MS and 6 years to generate a PhD. This is due to several causes, such as defficiencies in the undergraduate training of many of the students (leading to longer periods of adaptation to the work at the graduate level), the excessive emphasis in formal courses in some of the graduate programs (delaying the initiation of thesis projects), and delays in the research work due to erratic support of the investigators by the granting agencies.

One short-term measure to decrease the time for producing a PhD is the elimination of the Master's degree as a pre-requisite for studies at the PhD level, which has been customary in many of the graduate course programs. This pre-requisite no longer applies, in some of the courses, for students that demonstrate a PhD potential. It is to be hoped

that others will adopt a similar attitude, and regard the MS no longer as a necessary step for obtaining a PhD, but as a terminal degree for those students that do not qualify for the PhD degree.

However, the problem of the lack of proper undergraduate preparation of a good number of the students is not amenable to short-term relief, and will continue to impose the use, for correction of previous defficiencies, of some of the time that should be dedicated to graduate level work.

(c) Shortage of good candidates for graduate studies

The supply of good candidates for the graduate courses is hindered by the lack of career incentives, since the prospects for employment after completion of the graduate programs is mostly limited to the universities, which offer few positions with low salaries. As a consequence, many of the brightest students are channeled to more atractive activities after graduation.

Incentives for research and development programs in the private sector, as mentioned above, would help to improve the career prospects and attract more qualified students to the graduate courses.

A program that has been successful for many years is the awarding of scientific initiation ("iniciação científica") fellowships, which allow early recruitment of undergraduate students for part-time participation in scientific research. This allows the detection of individuals with scientific vocation that may be attracted to a scientific career, which would not otherwise occur. Furthermore, these students are much better prepared for entering the graduate courses, and usually take much less time to reach their PhD degree. In recognition of its merits, the scientific initiation program of the CNPq has been strengthened in recent years, and it is hoped that this policy will be continued.

Career opportunities

Despite the widespread *need* for qualified personnel in the physiological sciences in Brazilian universities, the *demand* for the new Masters and Doctors is discouraging, since the Brazilian civil service rules, particularly in the federal system ("regime jurídico único") make it almost impossible to replace non-productive personnel with new people. Therefore, the personnel turnover is very slow, and the creation of new teaching and research posts is insufficient to promote a substantial growth in the number of active scientists in our universities.

It is to be hoped that a repeal of the "regime jurídico único", to be replaced by a special regime for the universities, as proposed in an amendment to the Constitution

(Covas and Passoni, 1992, p. 82), meets with congressional approval, allowing a more flexible policy of hiring new scientific personnel and replacing non-productive individuals.

One of the mechanisms to absorb recent Doctors, while waiting for admission to a more permanent position is the post-doctoral fellowship, which in other countries is an important source of manpower for scientific research. However, only a very small number of these fellowships are awarded in Brazil. This is not due to shortage of such fellowships, which are easily available from the federal and state granting agencies, but to a very small demand by the candidates.

It should be noted that, in spite of the small number of posts available for new Doctors, there is no significant unemployment of these people because the small output of the graduate courses is in great part absorbed by the system. Furthermore, post-doctoral fellowships for studies abroad are given high priority by the granting agencies, and such fellowships are very easily obtained by the best of the recent doctors who, upon returning to Brazil, tend to assume positions in the universities' staff. As a result, post-doctoral fellows play a very minor role in conducting the bulk of the research being done in the most productive groups, which relies mostly on the work of graduate students.

Thus, the policy of sending people abroad for their post-doctoral work, which is highly recommended from the point of view of their training, deprives Brazilian laboratories of a better trained segment of investigators which, in other countries, is responsible for a very important contribution to the scientific productivity of the most active groups.

State of scientific research in the different disciplines

Biochemistry and Molecular Biology

Among the physiological sciences, Biochemistry is the most active in Brazil, in terms of number and productivity of scientists, and is also the discipline for which more performance indicators are available. In particular, a bibliometric analysis of the scientific production from the 19 most active groups (comprising 80 - 90 % of Brazilian active biochemists) during the period 1970 - 1985 (Meneghini and Fonseca, 1990; Meneghini, 1992) is an attempt to quantitate the Brazilian research effort in this area. During that period, the 487 investigators published ca. 3,000 papers in international journals (an average of 0.45 papers per year per person). These papers generated about 17,000 citations in the period from 1983 to 1987, i.e., 5.7 citations per paper. These numbers are not far behind those seen in first world countries, but the authors emphasize the heterogeneity of their sample, with large differences in productivity between groups and individuals, and a strong concentration of the most productive groups in São Paulo state and the city of Rio de Janeiro.

In spite of the very small size of the biochemical community in Brazil, with about one active biochemist for 300,000 inhabitants, and although its productivity is still low when compared to that observed in the more advanced countries, it appears to have reached a certain level of maturity, and the ever increasing influence of molecular biology has brought added vigor to the research in this area. Weak points are still the lack of more expensive equipment, such as mass spectrometers, NMR spectrometers and X-ray crystallography equipment (see below).

Biophysics

All federal universities in Brazil have Departments of Biophysics, but serious research in this discipline is performed in very few of them, with a prominence of the Instituto de Biofísica Carlos Chagas of the Federal University of Rio de Janeiro. Because of its interdisciplinary nature, research in Biophysics is pursued also in many departments of Biochemistry and Physiology and it is difficult to distinguish between these specialties when estimating their scientific productivity. In fact, many of the scientists surveyed in the above mentioned study of the productivity of biochemists were from the two most productive departments of Biophysics in the Country.

The main problem faced by this area is the lack of modern instrumentation, due to the high cost of equipment for physico-chemical and structural studies, such as those involving nuclear magnetic resonance, X-ray difractometry and mass spectrometry. Because of the costs involved in acquiring and maintaining such equipment, it is recommended that a coordinated effort be sponsored by federal and state scientific research agencies to create national centers where more expensive equipment could be used by scientists from different institutions. These centers would not be just service facilities, but really congregate groups of specialists working in projects involving intense use of the equipment.

One such laboratory should be a mass spectrometry facility dedicated to biochemical and biophysical problems. There are numerous mass spectrometers located in many institutions in Brazil, but none of them is adapted and accessible for use by biologists. Therefore, a national laboratory for mass spectrometry should be created, based in a pre-existing protein chemistry group which should be supported with equipment, personnel training and maintenance.

Another much needed national center would be a nuclear magnetic resonance laboratory where at least one large machine (for instance, 500 MHz) would be dedicated to biochemical and biophysical research.

A facility for X-ray crystallography should also be promoted by a joint effort of the few laboratories where biological problems are studied with that technique. In this respect,

it would be recommended that a station for protein crystallography be included in the synchroton being built by the National Laboratory for Synchroton Light project.

Physiology

Physiology, among the physiological sciences, has the longest tradition of scientific research in Brazil, the first nucleus responsible for a physiological school being the laboratory initiated in Rio de Janeiro in the twenties by Alvaro and Miguel Osório de Almeida. Disciples of these two pioneers irradiated to medical schools and other institutions in Rio de Janeiro and São Paulo, where they were joined later by the first Brazilian physiologists trained in the United States and Europe. The growth of the discipline was slow until the late fourties, when the full time regimen was implanted, initially in the Faculty of Medicine of São Paulo, and later in the federal universities. A faster growth was observed in the sixties and seventies, with the creation and development of formal graduate courses and their strong support by federal agencies. In the last decade, however, a stagnation has been observed in the area, which is evidenced by the slow growth in the scientific productivity of the most prominent departments, where a very productive generation of scientists trained in classical physiology are only slowly being replaced by a new generation trained in more modern methods and concepts. It is desirable that a greater number of young physiologists acquire post-doctoral training abroad in laboratories where they will become familiar with the new techniques and concepts of Cell Biology and Molecular Biology.

Pharmacology

As an offspring of Physiology, Pharmacology was initiated in different institutions by investigators that originated from the main physiological groups in the Country, and since the fourties have been responsible for a growing scientific production in the area. However, in Pharmacology, as in Physiology, a certain stagnation has been observed in the last decade, which may also be attributed to a lack of renovation of the scientific leadership. Here, also, the retiring prominent investigators are not being adequately replaced by a new generation of pharmacologists trained in the more modern methodologies, and the future of the discipline in Brazil depends on more intensive training of post-doctoral fellows in these methodologies.

Parasitology

The most productive research groups in Parasitology are those involved in the study of Trypanosomas and Leishmanias. In the annual meetings on Chagas disease about 400 papers are presented, which are at the front of the best research done on the subject in the world. In contrast, the annual meetings of the Brazilian Society of Protozoology (which are conjugated with those on Chagas disease) receive a much smaller number of

contributions (59 in 1992). Important subjects such as malaria and amoebiasis are the object of very little good level research by basic parasitology groups.

The impressive development of Tripanosoma research in the last 20 years was in great part due to a special program ("projeto integrado") funded by the CNPq, which was responsible for coordinating efforts of different groups working in Chagas disease and for attracting new investigators to the area, with remarkable success.

Such "integrated projects" have been discontinued by the CNPq, but the success of the Chagas disease group suggests that new programs on similar lines should be promoted for other areas such as malaria.

Microbiology

The evolution of microbiology in Brazil has occurred mostly in medical schools, where applied microbiology has been, in general, privileged in relation to important topics of basic microbiology such as the physiology and genetics of micro-organisms. Also in this discipline, traditional methodology is prevalent, instead of multidisciplinary approaches that make use of the modern techniques of cell biology and molecular biology. As a result, the scientific production in this area is relatively low, when compared with most of the other physiological sciences. In particular, important specialties such as Virology and Food microbiology and toxicology, are neglected, and should be the object of concerted efforts, such as the promotion of special programs, which have been successful in improving the productivity of other areas, such as the protozoa research which was greatly favoured by the "integrated project" for the study of Chagas disease .

Immunology

Immunology is one of the disciplines of the physiological sciences which has experienced the greatest progress in the last decade, at the international level, with a great impact on the development of biotechnology. In Brazil, immunology also has been the object of growing interest, although the number of active groups of immunologists is still small. Of the 39 Brazilian universities, only 19 (48%) offer undergraduate programs in immunology, and of the 71 medical schools only 22 (31%) offer courses in immunology. There are relatively few lines of research being pursued in a small number of groups, and there is little interaction and collaboration between these groups and with investigators in other disciplines such as biochemists, pharmacologists, geneticists, epidemiologists, etc. These defficiencies will only be reduced with the increase in the mass of investigators in the area, which depends on an active support of personnel training by graduate courses in the more developed institutions in Brazil, which should be strengthened by bringing foreign visiting professors, and by increasing post-doctoral training abroad.

This area, including Anatomy, Histology, Embryology and Cell Biology, has been dominated by the anatomists and histologists, who have played an important role
in the morphological sciences, distributed by ca. 80 medical schools as well as in 90 and isolated institutions involved in undergraduate teaching in biological and health
research, namely those that participate in the accredited graduate courses. In 1991 this to 130 docents holding Doctor's degrees, who published 86 papers in international journals (0.66 papers/docent.year).

in the scientific productivity of this area has been hampered by the contrast
the need to teach classical anatomy and histology to medical and biological students and
this area has been slow to adopt new concepts and methodologies to their research, in a poor performance that is reflected in the low grades given by CAPES's peer review
that are rated best in other areas.

One
conditions in this area is the "Programa Setorial de Microscopia Eletronica", financed by P, which gives support to several electronic microscopy laboratories. Similar coordinated
morphological departments of Brazilian universities should be promoted.

Conclusions and recommendations

The data obtained for this report from the different sources are sometimes contradictory or outdated, and some effort and common sense were necessary to arrive at plausible figures, which however cannot be considered
should be subjected to revision when more reliable and updated data are made available

be hoped that these agencies (CAPES, CNPq, FINEP), which for years have been data about the scientific community in Brazil, will make an effort to recover these data for useful
performance of the different areas.

Interaction between basic science and technology

The industries depend very little on the universities for their know-how, and do not hire a significant number of Masters and Doctors formed in the graduate schools. This situation might be improved if changes are introduced in the industrial policy of the Government favoring investments by the private sector in science and technology leading to a significant research and development effort in Brazil.

It is to be hoped that the recent trend to improve the scientific productivity of federal and state biotechnological institutes will be sustained, and that these institutions will have success in their efforts to attain a more politically independent status, and to provide more attractive careers for their scientific staffs.

Funding

The investment, by the Brazilian Government, of 0.7% of the GNP in science and technology might be considered appropriate if the funds were adequately administered and if it were supplemented by a significant contribution from the private sector.

The main federal agencies supporting science (FINEP, CNPq) were greatly affected by the economic and political crisis suffered by the Country in recent years. Unless this negative trend is quickly reversed, irreparable damage may be suffered by research groups and institutions.

PADCT, after the recognition that basic science must also be supported, may have an important effect in avoiding pulverization of the available resources by concentrating its support in the most viable projects and productive groups. However, the Brazilian government must meet its obligations to this program, since its contribution is essential to support the local expenditures of the projects.

As a result of chronic lack of funds, or of the bad planning in the distribution of available funds, some important investments in more expensive equipment have been neglected. Prominent investigators in the different disciplines should be consulted about bottlenecks in their areas due to lack of modern instrumentation, and co-operative projects should be encouraged to acquire high cost equipment for common use. National centers should be supported, where more expensive equipment could be used by scientists from different institutions. These centers would not be just service facilities, but really congregate groups of specialists working in projects involving intense use of the equipment. Important examples of these laboratories that are much needed for the progress of physiological science research would be a mass spectrometry facility, and a nuclear magnetic resonance laboratory dedicated to biochemical and biophysical research. A facility for X-ray crystallography should also be promoted, and a station for protein crystallography be included in the synchroton being built by the National Laboratory for Synchroton Light project.

"Integrated projects" funded by the CNPq, which had great success in the case of Chagas disease group, should be organized for other areas, such as malaria and the application of modern techniques in morphology, physiology and pharmacology.

The distortions in the regional distribution of scientific research groups are not to simple solutions tried in the past, such as CNPq's "regional scientific development"
conditions and the efficiency of the efforts of local groups to conduct scientific research. intensification of the cooperation between graduate courses of the less and more developed
from the less developed areas abroad for obtaining their doctorates. An interesting is the establishment of official co-operative programs between universities of the
graduate training in their local universities.

Personnel training

improve the efficiency of graduate training in the physiological sciences, the shortage
scientist abroad, and by intensifying the "sandwich fellowship" programs of CAPES and which are proving to be more advantageous then supporting "full PhD" fellowships abroad.

It is to be hoped that a repeal of the "regime jurídico único", to be replaced by a the universities, meets with congressional approval, allowing a more flexible

In spite of the small number of posts available for new Doctors, there is no unemployment of these people because of the small output of the graduate courses.
be fostered as a mechanism to temporarily absorb recent Doctors into active research

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TABLE I - SUPPORT OF BIOLOGICAL SCIENCES BY DIFFERENT SOURCES - 1991 (IN US$ MILLIONS)

Source	Fellowships	Projects	Total	%
CNPq	23.89	8.86	32.75	34.3
FINEP*	-	12.96	12.96	13.6
CAPES	12.54	-	12.54	13.1
PADCT	-	6.74	6.74	7.0
FAPESP	1.74	23.29	25.03	26.2
Other State Foundations	0.32	5.25	5.57	5.8
Total	38.49 (40.3%)	57.10 (59.7%)	95.59	100%

*Excluding funds from PADCT

TABLE II - FEDERAL GRANTS FOR RESEARCH PROJECTS: 1987-1991

	CNPq		FINEP	
Year	No. of projects	Amount	No. of projects	Amount*
		10^6 US$		10^6 US$
1987	709	5.0	111	13.3
1988	640	4.1	117	16.4
1989	517	2.7	166	19.3
1990	731	12.5	113	10.2
1991	922	**	70	5.6

*Excluding funds from PADCT

**Although ca. US$ 20 million were granted to 922 projects in 1991, this money was not available that year nor in 1992, due to severe cuts in CNPq's budget execution.

TABLE III. INDICATORS OF THE SIZE OF THE PHYSIOLOGICAL SCIENCES SCIENTIFIC COMMUNITY (1992)

		DISCIPLINES						
		Biochem.	Biophys.	Physiol.	Pharmacol.	Morphol.	Immunol.	Paras
Holders of Doctor's degree		436	88	329	244	210	193	23
Career Fellowships	Pesquisador I	62	12	35	34	25	32	2
	Pesquisador II	106	24	81	71	36	43	5

Sources: CNPq, CAPES and the Brazilian Societies of Biochemistry, Biophysics, Physiology, Pharmacology and Experimental Therapeutics, Anatomy, Electromicrography, Immunology, Microbiology, Chagas disease (Trypanosoma and Leishmania) and Protozoology (malaria and other protozooses).

TABLE IV. NUMBER OF GRADUATE COURSES BY REGION (1991)

		DISCIPLINES					
Region	**Levels**	Biochemistry	Biophysics	Physiology	Pharmacology	Morphology	Immunolo
South-East	Master	8	1	4	6	8	4
	Doctor	7	1	2	3	4	3
South	Master	1	0	1	1	1	0
	Doctor	1	0	1	0	0	0
North-East	Master	2	1	2	2	0	2
	Doctor	0	0	0	0	0	0
Central	Master	0	0	0	0	0	1
	Doctor	0	0	0	0	0	1
North	Master	0	0	0	0	0	0
	Doctor	0	0	0	0	0	0
Totals	Master	11	2	7	9	9	7
	Doctor	8	1	3	3	4	4

Source: CAPES

TABLE V - NUMBER OF ABSTRACTS PRESENTED AT THE LAST ANNUAL MEETING AND OF FULL PAPERS PUBLISHED PER YEAR (IN THE LAST 5 YEARS) IN INDEXED BRAZILIAN AND INTERNATIONAL JOURNALS BY BRAZILIAN INVESTIGATORS IN THE PHYSIOLOGICAL SCIENCES

	DISCIPLINES						
	Biochemistry	Biophysics	Physiology	Pharmacology	Morphology	Immunology	Parasito
Abstracts	732	101	448	264	456	183	450
Brazilian Journals	81	8	38	56	80	39	48
International Journals	70	5	47	76	64	12	25

TABLE VI. NUMBER OF STUDENTS AND DEGREES AWARDED IN DECEMBER 1991

		DISCIPLINES					
	Degrees	Biochemistry	Biophysics	Physiology	Pharmacology	Morphology	Immunolog
Number of students	Master	351	126	133	196	56	105
	Doctor	273	157	54	73	83	73
Degrees Awarded	Master	93	18	36	40	11	10
	Doctor	37	17	12	6	14	6

Source: CAPES

TABLE VII - CNPq FELLOWSHIPS FOR POST-GRADUATE TRAINING ABROAD (1992)

Level	DISCIPLINES						
	Biochemistry	Biophysics	Physiology	Pharmacology	Morphology	Immunology	Par
Specialization	2	2	1	3	3	3	
M.S.	2	0	0	0	3	10	
PhD	22	5	15	19	6	12	
Post-doctoral	11	7	19	12	4	13	

Sources: CNPq and CAPES (The numbers represent the fellowships granted by the two institutions in 1992