The shifting fortunes of **global science**

A microbiology laboratory in Athens in 2004. Despite steep growth in recent years, GERD in Greece (0.6 % of GDP in 2001) remains the lowest of all EU15 countries, on a par with the ratios for newcomers Estonia, Lithuania and Slovakia

Remarkable growth in a small number of emerging Asian economies, led by China, is narrowing the gap with North America, Europe and Japan in research and development (R&D), according to the *UNESCO Science Report 2005*[1] published in December. The report analyses the state of science and technology (S&T) around the world through the eyes of a team of independent experts, each of whom is writing about his or her own country or region. Here are some of the report's findings.

Without a doubt, science is undergoing rapid change. By 2002, the developing countries were contributing 22% to world expenditure on R&D, compared with just 16% five years earlier. Worldwide, gross expenditure on R&D (GERD) rose sharply over the same period, from US$547 billion[2] to US$830 billion.

China becoming a force to be reckoned with

'The most remarkable trend is to be found in Asia, where GERD has grown from a world share of 27.9% in 1997 to 31.5% in 2002', notes the report. This dynamism is driven largely by China which, in 2002, counted more researchers than Japan. In the space of just five years, China has gone from contributing 3.9% of world GERD to 8.7%, a greater share than Germany (Figures I and II).

In its five-year plan to 2005, China listed information technology, biotechnology, new materials technology, advanced manufacturing technology, aerospace and aeronautics as all being fields 'in which China should aim for breakthroughs'.

Patents granted by China have nearly doubled in just four years (to 132 000 in 2002). However, whereas invention accounted for 73% of patents granted by China to foreigners in 2001, it accounted for just 5% of patents granted by China to local residents (the great majority falling into the two remaining categories of utility model and design).

'The emergence of China is not yet reflected in patent statistics', notes the report, a trend less surprising than it may seem, as patents are indicative of a mature business environment and China's Company Law dates back only to 1993. High-tech goods currently make up just 21% of China's manufactured exports[3] (enough nevertheless to place China seventh worldwide in terms of volume). 'At the same time, the dynamics are clearly visible', observes the report. 'China now imports more scientific instruments, electronics and telecommunications products and electrical machinery than Japan'.

High-tech goods have come to represent as much as 72% of Filipino manufactured exports, 50% of the total in Malaysia and 32% in Thailand. This remarkable feat is explained by the fact that 'multinationals and companies in developed countries have been stepping up original equipment manufacture operations in Asian countries'.

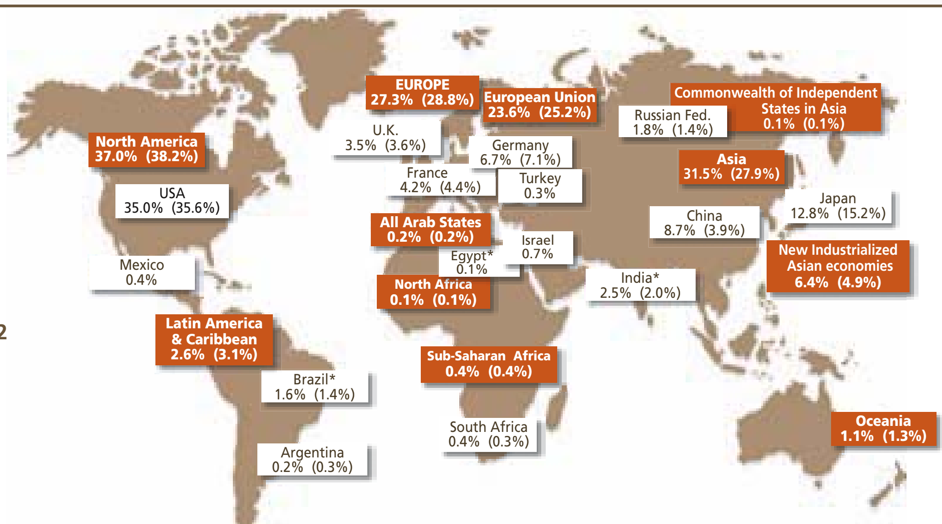
Asia's world share of scientific publications has gone from 16.2% to 22.5% over the past decade. China and the newly industrialized Asian economies have nearly tripled their world share of scientific publications, although India has actually lost ground (Figure III).

Shanghai in 2004. Chinese expenditure on R&D more than tripled between 1997 and 2002, from US$21 billion to US$72 billion. The reason for this steep rise lies not only in China's strong, sustained economic growth but also in its stronger commitment to R&D: 0.8% of GDP in 1999 and 1.2% of GDP in 2002, with plans to increase this proportion to 1.5% of GDP by 2005. China's biggest neighbour, India, itself crossed the 1% threshold in 2004 and plans to raise its own expenditure on R&D to 2% of GDP in coming years. The economies of both China and India grew by close to 10% in 2005

Figure I

WORLD SHARES OF GERD, 1997 AND 2002

Figures for 1997 are between brackets



Source: *UNESCO Science Report 2005*; data for 1997: *A World of Science*, January 2004

**Data for Brazil, Egypt and India are 2000 rather than 2002*

Asian science is booming but one factor overshadows this glowing picture. 'With hundreds of millions of Asian children still living in poverty', regrets the Director-General of UNESCO in his foreword to the report, 'the benefits of R&D are still not reaching large segments of the population who are deprived of such basics as good nutrition, access to safe water, sanitation and shelter'.

A less dominant Triad

The USA remains remarkably dynamic, alone representing more than one-third of the world's scientific activity, yet just 5% of the world population. This share has nevertheless been slightly eroded.

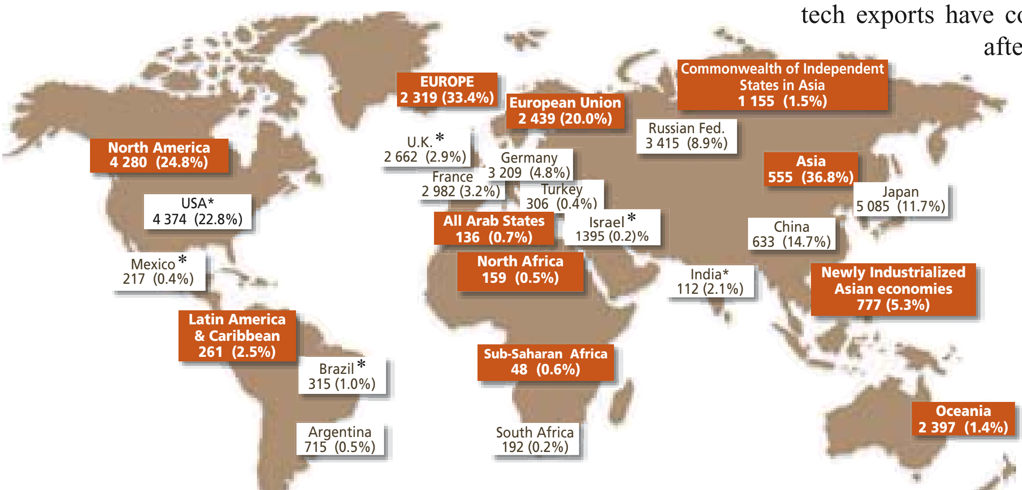
The world shares of Japan and Europe in terms of GERD are likewise diminishing, although Japan and Europe have actually strengthened their hold on scientific publications over the past decade.

Doubt and opportunity in Europe

The entry of 10 new Member States[4] in 2004 – thereby swelling the European Union's (EU's) population by 75 million (or 20%) – offers fresh opportunities for intra-European research but also reinforces disparities. Not one of the new members measures up to the EU15 average of 1.9% (GERD/GDP ratio), itself well below the R&D effort of the USA (2.8%) and Japan (3.1%).

Like Central and Eastern Europe, the Russian Federation is gradually recovering from the painful transition to a market economy following the disintegration of the Union of Soviet Socialist Republics (USSR) in 1991. After slipping from 2% to below 1% of GDP in the mid-1990s, GERD in the Russian Federation has now climbed back to 1.3% of GDP (2002). Civil R&D was allocated 15% more from the federal budget in 2004 than the previous year and, as scientists emerge from isolation, the Russian Federation's share of scientific publications is growing.

One country to watch in coming years will be Turkey (70 million inhabitants), whose 'relative growth of 9% per annum is one of the better rates in the world'. Between 1990 and 2000, GERD trebled to US$ 2.7 billion (0.6% of GDP). The business sector's share of R&D funding has also grown, from 31% in 1993 to 43% in 2001. Publications by Turkish scientists trebled between 1997 and 2002 and high-tech exports have come to represent 3% of total exports, after growing at a much greater pace (43%) than high-tech imports (16%) in the five years to 2001.



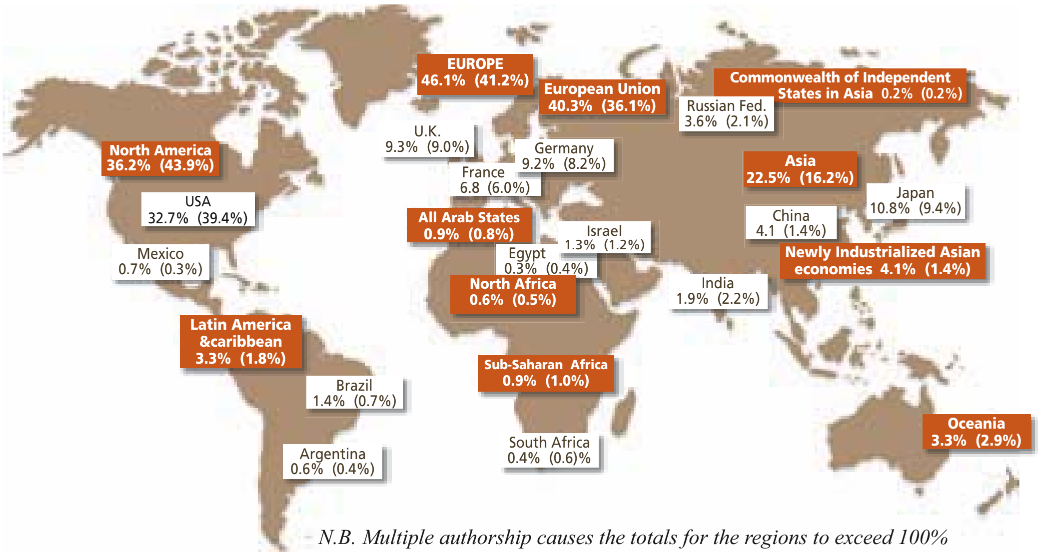
**Data for Brazil are for 2000, for Mexico and USA 1999, for India and UK 1998, for Israel 1997 ; N.B. Researchers worldwide = 5.5 million*

Figure II

RESEARCHERS IN THE WORLD, 2002

Per million inhabitants and as a world share (between brackets)

Source: *UNESCO Science Report 2005*



N.B. Multiple authorship causes the totals for the regions to exceed 100%

Figure III

WORLD SHARES OF SCIENTIFIC PUBLICATIONS, 1991 AND 2001

Figures for 1991 are between brackets

Source: *UNESCO Science Report 2005*

'Latin America not getting it together'

Latin America and the Caribbean accounts for just a fraction of world GERD and this share appears to have slipped between 1997 and 2002 (from 3.1% to 2.6%). Just three countries – Brazil, Mexico and Argentina – contribute 85% of the total. In the Caribbean, only Cuba[5] meets the regional average for GERD of 0.6% of GDP.

'The world is globalizing and Latin America is not even getting it together', regrets the report. This is explained by the fact that attempts at intra-regional integration have come up against persistent 'obstacles connected with development problems and political and financial instability'.

Having a small pool of researchers has not prevented Latin America from increasing its share of world publications between 1991 and 2001. Although Latin American scientists still co-author papers predominantly with their counterparts from Europe and North America, collaboration among Ibero-American colleagues has progressed, as has co-authorship with Asian scientists: from *circa* 6% in 1997 to over 18% in 2001.

Better prospects for Africa?

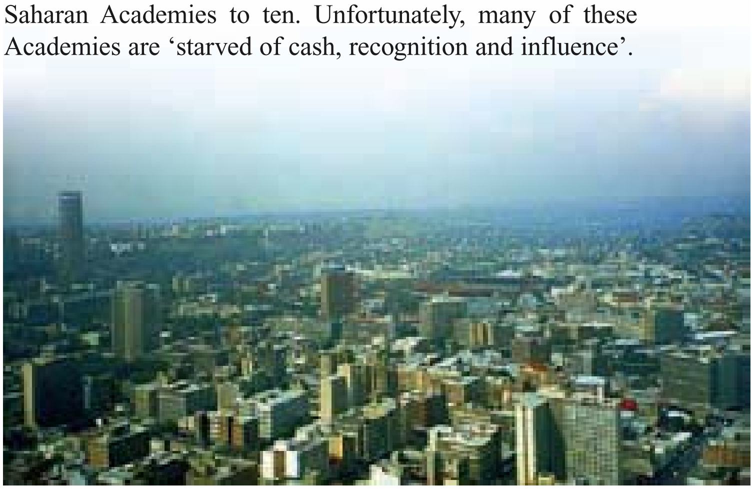
Africa remains a continent of stark contrasts. Whereas 'many countries are struggling simply to get back to where they were in the 1970s and 1980s[6], South Africa and Egypt can boast of more solid research systems.

South Africa contributes 90% of GERD south of the Sahara, with research capabilities that span aeronautics, nuclear engineering, chemistry, metallurgy, agriculture and medicine. By contrast, research in median Africa tends to be circumscribed to the two latter fields.

Egypt stands out in North Africa for the strength of its research apparatus, most productive in chemistry and engineering. Scientific output in the Maghreb, where countries have only been developing their national research systems since the 1970s, has been growing however by 10% a year since 1980. These countries have good capacities in medicine, agriculture, physics, chemistry and engineering.

A relative newcomer to the African landscape, the New Partnership for Africa's Development (NEPAD) encompassing 53 countries was launched by the African Union in 2001. The report argues that NEPAD has greater prospects for success than previous reform efforts because it 'emphasizes sensible goals'. NEPAD's plan of action for S&T ties investments to such immediate needs as poverty elimination, improvements in public health, access to safe drinking water and environmental protection. It also promotes regional centres of excellence as a key strategy for boosting African collaboration and both South–South and North–South co-operation.

Of note is the growing number of Academies of Science on the African continent, including the Arab Academy of Sciences founded at the initiative of UNESCO in 2002 and headquartered in Lebanon. The founding of the Zimbabwe Academy of Sciences in 2004 brought the number of Sub-Saharan Academies to ten. Unfortunately, many of these Academies are 'starved of cash, recognition and influence'.



Johannesburg in 2004. South Africa devoted US$3.1 billion to R&D in 2002, the equivalent of 0.7% of GDP

A more competitive global environment

Globalization is offering new opportunities through greater international cooperation. This is 'not only helping countries to catch up but is also becoming indispensable to the very exercise of science'. But globalization is also bringing its own set of challenges, not least of which is a more competitive environment.

In the USA for example, 'research universities face increasing international competition, despite their high quality'; over the past decade, Asia's world share of scientific publications has grown substantially and Europe has overtaken the USA. 'If one limits this survey to publications and citations in the highest impact journals, however, the USA remains very much in the lead', notes the report.

India has now been overtaken by China in terms of publications registered in the Science Citation Index of the Institute of Scientific Information (USA). Over the past five years, S&T policy in India has focused on intellectual property management favourable to patents. However, with scientific publications stagnating, this strategy is now being questioned in Indian S&T circles.

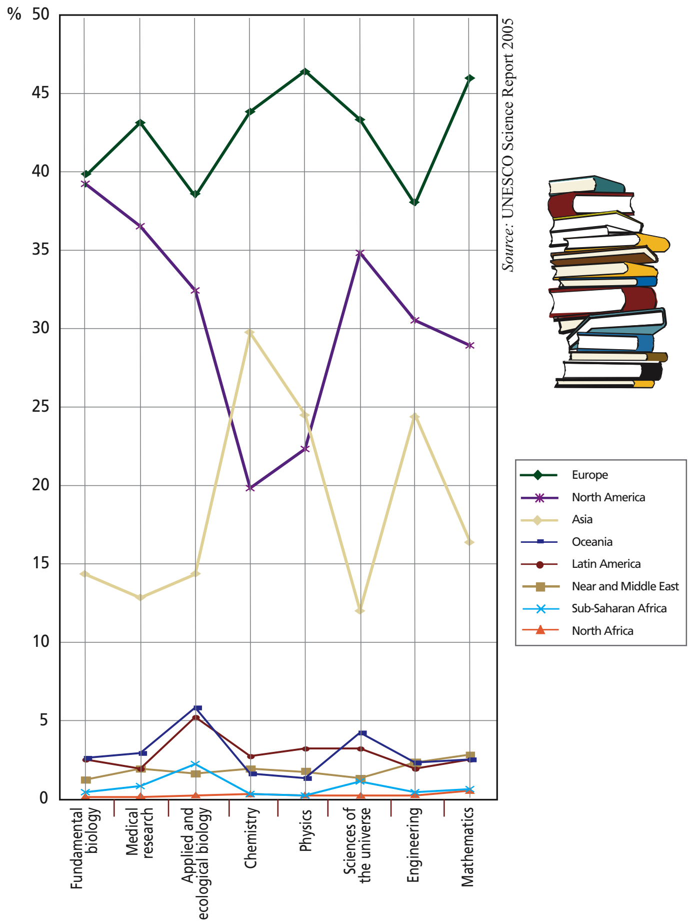


Figure IV **WORLD SHARES OF SCIENTIFIC PUBLICATIONS, 2001**
By discipline

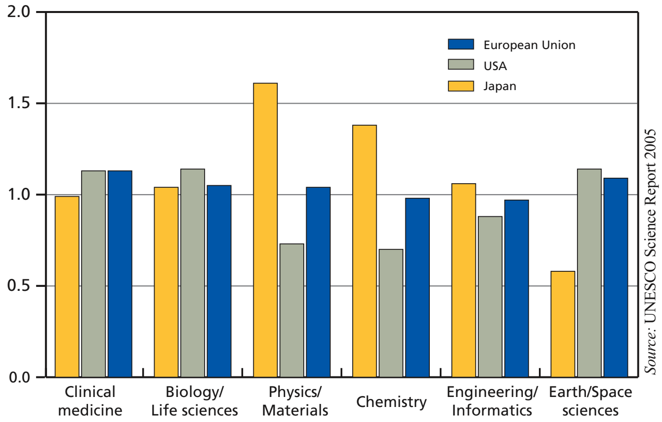


Figure V **SCIENTIFIC PROFILES OF THE TRIAD, 2002**

The USA could be described as 'Japan's opposite', insofar as it shows a strong leaning towards research in life sciences and Earth/space sciences but accords a low priority to physics/materials science and chemistry. The EU, on the other hand, maintains a balance in all six scientific fields (Figure V). The new members should enhance the EU's dominant position in publications, as their strengths lie in mathematics, physics and chemistry. However, at a time when Europe is losing ground in technology, the new members are unlikely to make a difference. In technology and innovation, the USA remains unrivalled.

This said, even US companies 'are running harder to succeed against global competitors in technology'. Moreover, after decades of strong growth, industrial R&D in the USA has got off to a slow start in the new century: expenditure has declined three years in a row and 'more companies [were] planning to reduce R&D expenditure [in 2004] than to increase it', according to an Industrial Research Institute survey.

The Russian Federation is now entering the innovation market, despite problems which impinge on the country's competitiveness, such as inertia in modernizing heavy industries inherited from the Soviet era or in adapting the country's intellectual property law to the market economy. By 2001, 27% of Russian entities performing R&D were privately owned.

Brain drain a persistent problem

Brain drain continues to plague many countries. Even India, which can boast of remarkable achievements in software development[7], space, biotechnology and pharmaceutical research, still sees many of its highly trained graduates lured abroad, mainly to the USA.

This shows that having a strong university system may be one bulwark against brain drain but is not sufficient in itself to overcome the problem. The example of China, where 'approximately one-third of those who go abroad are returning every year', illustrates that higher development at home constitutes the single most effective magnet for attracting researchers back to their country of birth.

US institutions draw their largest foreign contingents of students from China and India. There are concerns in the USA that 'more stringent and protracted procedures for obtaining US entry visas since the terrorist attacks of 2001' could dissuade students from applying for a visa. The number of applications for student visas has already dropped to 236 000 (2003), from 320 000 in 2001.

The socio-economic trauma of transition to a market economy led to a veritable haemorrhage of researchers in the Russian Federation and former satellite states of the Soviet Union in the 1990s, through both internal and external brain drain. The number of Russian researchers, for instance, shrank from 878 000 in 1991 to 519 000 in 1995 (*World Science Report 1998*), before stabilizing at around 492 000 (2002). Brain drain has also levelled off in Central and Eastern Europe but continues to pose a major headache in South-East Europe.

Today, the Russian Federation represents the fourth-biggest pool of researchers in the world, behind the USA, China and Japan. The socio-economic status of Russian researchers remains low, however, and each disposes of much less funding for R&D than his or her counterparts in developed countries.

The free market ethos which accompanied globalization after 1980 has been particularly devastating for Africa, having led to a disengagement of government on a continent where the private sector was unable to fill the void. 'To avoid humiliation and a huge downgrading of their social position, many academic figures emigrated', either to the North or to 'other African countries where pay was higher', recalls the report. Although African scientists acknowledge a high degree of job security, 52% of them in the Republic of South Africa are dissatisfied with their salaries, according to a 1999 survey, compared to 69% in North Africa and 92% in median Africa.

The importance of a national vision

The report underscores the importance of a national vision. In Africa, for example, the S&T market is dominated by international donors, aid programmes and multinational companies. The incentives they provide to African researchers bear little fruit because they are not matched by national S&T systems capable of offering careers.

Similarly, in the Arab region, the main input to technology comes from turnkey investments by large foreign companies and the technology thus acquired fails to take root. 'In the past three decades, the Arab world has spent US$1 000 billion on turnkey projects, more than 20 times the amount spent within the Marshall Plan to rebuild Europe after the Second World War', states the report. It warns that 'Arab economies dependent on oil and mineral resources will not be able to sustain development as resources become depleted' because S&T are not a priority item on the agenda of Arab political leaders.

Even in Latin American countries with a more developed S&T sector, caution is recommended where international collaboration is concerned, as 'this should bring not merely technology transfer but also capacity-building'. The report points to 'untapped potential in Latin America and the Caribbean for the horizontal transfer of knowledge and technologies under mutually advantageous conditions'.

One example of how technology transfer can pervert the cause of development is the plan by the Ford Motor Company in the 1970s to have different parts of the Ford model made in different Asian countries. 'The plan exploited economies of scale by producing large quantities of the same part in one location and made sure no country acquired the technology to make a complete car', the report recalls. External influences are expected to diminish in East and South-East Asia, where they 'have tended to be divisive'. Countries 'have reached capabilities that make S&T cooperation [within the region] feasible but it is still a daunting task to identify meaningful areas for synergistic collaboration', notes the report.

The Indian exception

The global patent system remains the object of passionate debate. 'Ever more parties recognize that the ... Agreement on Trade-Related Intellectual Property Rights (TRIPS) cannot adequately and fairly cope with issues such as the patentability of genes and natural resources', observes the report. One burning issue in recent years has been the need to find affordable solutions for treating infectious diseases plaguing the developing world.

'The Indian exception' illustrates the struggle by some countries to adapt the global patent system. The Indian Patents Act of 1970 had effectively permitted 'reverse engineering' by not allowing product patents in drugs, food and chemicals but only process patents in these fields for up to seven years. This had enabled India to become self-sufficient in every essential drug and to gain 8% of the world pharmaceuticals market.

A patent ordinance effective since 1 January 2005 has brought India into conformity with TRIPS by amending the Patents Act of 1970. The new ordinance extends product patent protection to all fields of technology, including medicine, food and chemicals, for 20 years. It includes a provision for granting compulsory licences for export of medicines to countries with insufficient or no manufacturing capacity, in accordance with the 2001 Doha Declaration on TRIPS and Public Health. This means that Indian companies will be able to produce and export AIDS drugs to African and South-East Asian countries.

In India, there are hopes that the new ordinance will encourage domestic pharmaceutical companies to emphasize R&D-based innovative growth, thereby enabling the country to 'become a global research hub'.

Patent or perish?

Has academia become *too much* a department of industry? The report posits that 'the stronger ties between companies, universities and research institutes have brought centre-stage a number of crucial issues touching upon the very essence of public sector responsibilities. The quest for patentable research results or for income from clinical trials for example…has led entire university departments around the world into a grey area where values such as independence, integrity, collaboration, openness and public availability of results acquired by public money are put at risk'.

This has in turn spawned attempts to establish a new equilibrium where 'on the one hand, those values proper to academic activities are safeguarded and, on the other hand, the value of the results of research is recognized more explicitly'.

Finding an optimum balance

One universal factor emerging from the report is the importance of the private sector in sustaining R&D. The report cautions, however, that, since such funding is inevitably oriented towards short- and medium-term applications seeking rapid returns on investment, basic research everywhere needs to be able to rely on consistent public funding. (Even in the USA, 60% of all university research is funded by the federal government.) This is why a strong science policy remains essential to maintaining a coherent national science sector.

'China's small allocation to basic research (6%) is well out of line with practice in other countries', observes the report. This policy stems from a decision dating back to 1985 to emphasize the commercialization of S&T. (Enterprises now perform 61% of R&D in China.) 'There is now much debate among the scientific community in China as to whether a more balanced approach should be taken'.

In recognition of the fact that basic academic research is a source of technological opportunity, both the USA and Japan have set up Technology Licensing Offices in universities in recent years. In India, high-tech 'biotech clusters' have been developed in Bangalore, Hyderabad ("Genome Valley") and Delhi, home to India's major universities and government-supported laboratories. In these research hubs, public–private partnerships generate venture funds for innovation in biotechnology.

The lack of an R&D environment on campus poses a big problem in the Arab States, where the relationship between university research, teaching and industry is 'a three-way divorce'.

One handicap for Europe is the duplication of research, owing to the large number of research bodies compared to the USA. 'There seems to be agreement on the need for a European Research Council … which would create a 'uniform attractive force for the best scientists'.

The relative weakness of private sector involvement in research is one reason why Europe is lagging behind North America overall. The report notes that only 56% of R&D funding in the 15-member EU came from industry in 2001, compared to 66% and 69% in the USA and Japan respectively. In this context, the EU's declared goal of seeing its Member States devote 3.0% of GDP to GERD by 2010 seems overambitious, especially as two-thirds of this funding is to come from industry.

A number of European States are nevertheless leaders in innovation. Sweden tops the list, followed by Finland, Switzerland, the UK and Denmark. Sweden and Finland share the distinction of having a small population (*circa* 9 million and 5 million respectively) and of devoting two of the highest percentages of GDP to R&D in the world: 4.3% and 3.4% respectively. Elsewhere in Europe, observes the report, Germany, the Netherlands and France are losing momentum in innovation, even as Portugal, Romania and Turkey, among others, are narrowing the gap.

Susan Schneegans and Roni Amelan[8]

To download the report:
www.unesco.org/science/science_report2005.pdf;
To order a copy: www.unesco.org/publishing

1. *The* UNESCO Science Report 2005 *is the fourth in a series. Its predecessor, the* World Science Report*, was published in 1998. Data for 1997 in the current article are taken from a study comparing global R&D input in 1997 and 2000; this survey by the UNESCO Institute for Statistics was published in* A World of Science *2(1), January 2004*
2. *All US$ are purchase power parity dollars*
3. *According to Chinese statistics, high-tech exports fall into the categories of computers and telecommunications, life sciences, electronics, weaponry, computer-integrated manufacturing, aeronautics and space, opto-electronic technology, nuclear technology, biotechnology and materials design*
4. *Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia*
5. *On Caribbean science, see* A World of Science*, 4(4), October 2005*
6. *This is the case of Nigeria, for instance, which undertook a reform of its science system in 2004 that includes a joint review of investment, industry and innovation by UNESCO, UNCTAD, UNIDO and WIPO. One aim of the reform is to use strong oil receipts to diversify the economy*
7. *India's software market quadrupled in value to US$20 billion between 1997 and 2003*
8. *UNESCO Press*