Africa

JACQUES GAILLARD, MOHAMED HASSAN and ROLAND WAAST
IN COLLABORATION WITH DANIEL SCHAFFER

Current Science,

et al.,

1. In some African countries, external 'aid' to research and scientific cooperation came to account for to 75% or more of the national research budget, for example in Senegal (Gaillard *et al.*, 1997).
2. See in particular the chapters on Egypt, Kenya, Nigeria and Senegal.

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THE COLONIAL LEGACY AND THE EMERGENCE OF NATIONAL SCIENCE

- **knowledge**
- **organizational models**
- **strategic choices**

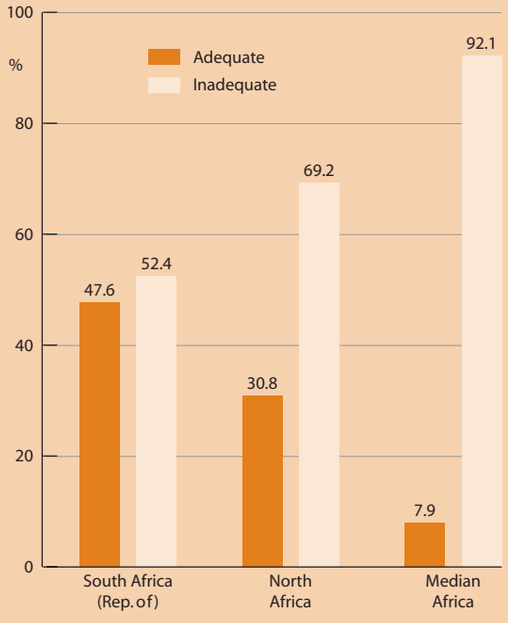
3. This study, coordinated by Roland Waast and Jacques Gaillard, and co-funded by the European Commission (DG Research), the French *Institut de Recherche pour le Développement* (IRD) and the French Ministry of Foreign Affairs, includes a comprehensive bibliometric study of science in Africa during the 1990s, country case studies carried out in 14 African countries (Algeria, Burkina Faso, Cameroon, Côte d'Ivoire, Egypt, Madagascar, Morocco, Mozambique, Nigeria, Senegal, Republic of South Africa, Tunisia, United Republic of Tanzania and Zimbabwe) and some 400 interviews with scientists conducted in the same countries.

A heterogeneous continent: North, South and Median Africa

Drugs from medicinal plants in Madagascar

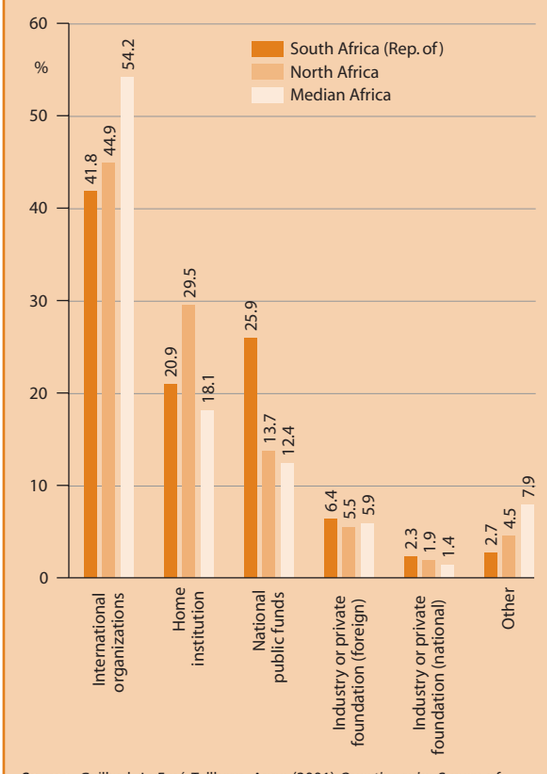
For more than 40 years, the Malagasy Institute of Applied Research, with a staff of 30, has sought to extract agents from indigenous plants to produce effective pharmaceuticals. For example, Madecassol®, derived from active agents of the Malagasy plant *Centella asiatica*, has been used to treat intense burns, leprous wounds and inflamed ulcers for more than a quarter of a century. Royalties earned by the institute for the critical role that its researchers played in the development of Madecassol® have generated thousands of dollars in annual revenues for the institute. The institute, however, does more than research the region's biodiversity for the purposes of developing pharmaceuticals. It also sells the drugs it helps create at subsidized prices to local populations, which allows them to enjoy the same health benefits as citizens residing beyond Madagascar's borders; it manages a health clinic that provides low-cost health care to nearby residents; it oversees a botanical garden to help preserve the region's rich biodiversity; it operates a small production facility that manufactures a variety of drugs for local distribution, including medicines to combat malaria, hepatitis and asthma; and it provides job opportunities to local residents in several different fields, both manual and technical, in a region where steady employment is hard to find. The Malagasy Institute of Applied Research was founded by Albert Rakoto-Ratsimamanga who continued to oversee its operations until his death in 2001. His wife, Suzanne Urverg-Ratsimamagna (an internationally recognized scientist in her own right), now heads the institute. She is expanding the scope and visibility of the husband and wife team's lifetime of work. Taking a long-term view, the institute's future rests on its ability to turn this family affair into a research institution that will continue to function long after its creators leave the scene. It is a challenge faced by many of sub-Saharan Africa's most successful scientific institutions.

Figure 1
ADEQUACY OF SCIENTISTS' SALARIES IN AFRICA, 1999
By region and major country



Source: Gaillard, J.; Furó Tullberg, Anna (2001) *Questionnaire Survey of African Scientists. IFS Grantees and INCO Beneficiaries.*

Figure 2
SOURCES OF RESEARCH FUNDS IN AFRICA, 1999
By region and major country



Source: Gaillard, J.; Furó Tullberg, Anna (2001) *Questionnaire Survey of African Scientists. IFS Grantees and INCO Beneficiaries.*

4. 702 African scientists responded to the questionnaire.

A BIBLIOMETRIC PANORAMA OF THE 1990s[5]

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Countries: the hierarchy

5. This section draws on Arvanitis *et al.* (2000).
6. Despite its limitations discussed elsewhere (Arvanitis and Gaillard, 1992), we consider that the PASCAL database can be used with some degree of confidence to characterize the relative importance of the main science producers and to pinpoint shifts.

Table 1
RESULTS OF THE IRD SURVEY ON RESEARCHERS IN AFRICA, 1999
Selected countries

	Staff in higher education	Researchers full time in the public sector	Researchers full time in the private sector	FTE[1] researchers	Researchers per million inhabitants
Algeria	16 000	1 200	700	3 000	100
Burkina Faso	700	200	0[2]	350	30
Cameroon	1 800	300	0	800	60
Côte d'Ivoire	1 200	500	0	600	55
Egypt	40 000	1 500	0	10 000	230
Kenya	1 800	600	0	1 000	35
Madagascar	900	260	0	300	35
Morocco	10 000	700	500	3 200	120
Mozambique	600	0	0	0	0
Nigeria	14 000	1 300	0	3 000	40
Senegal	1 000	435	0	600	80
South Africa (Rep. of)	17 000	8 500	5 000	13 000	350
Tanzania, United Rep.	1 400	0	0	600	70
Tunisia	9 000	800	400	3 000	350
Zimbabwe	1 100[3]	300	0	600	30

1 Full-time equivalent. 2 0 = negligible. 3 Includes private.

Source: Waast, R. and Gaillard, J. (coord.) (2000) *Science in Africa at the Dawn of the 21st Century*. IRD, Paris.

Group 1:

Group 2:

Group 3:

Group 4:

Group 5:

Countries: trends (1991–97)

Table 2
SCIENTIFIC ARTICLES PUBLISHED IN AFRICA, 1998

Selected countries

	Number of scientific articles	Articles per million inhabitants	Articles per billion US$ GNP
Algeria	241	8	5.5
Burkina Faso	72	7	26.0
Cameroon	167	12	18.0
Côte d'Ivoire	87	6	8.0
Egypt	1 313	120	17.0
Kenya	506	17	53.0
Madagascar	50	3	13.5
Morocco	510	20	14.5
Nigeria	450	4	14.5
Senegal	106	12	21.0
South Africa (Rep. of)	2 738	72	21.0
Tanzania, United Rep.	196	6	30.0
Tunisia	491	55	26.0
Zimbabwe	176	16	21.0

Source: Science Citation Index (North, South and East Africa); PASCAL (West Africa).

Table 3
SCIENTIFIC PRODUCTION IN AFRICA, 1991–97
By main linguistic and geographic area

	Scientific publications	Articles only	% of all scientific publications	% of all articles
English speaking (excl. South Africa)	10 639	9 155	21	22
French speaking (excl. Maghreb)	5 938	4 958	12	12
North Africa	18 906	15 542	37	37
South Africa (Rep. of)	13 997	11 813	28	28
Median Africa	881	759	2	1
Total	**50 361**	**42 227**	**100**	**100**

Source: Publications indexed in PASCAL (1991–97).

GLOBALIZATION: TENSIONS AND REORGANIZATION

et al.,

Table 4
KEY EDUCATION INDICATORS FOR AFRICA, 1990 AND 2000
Selected countries, in descending order of human development index

	Public expenditure on education as a % of GDP 1990	Public expenditure on education as a % of GDP 2000	Public expenditure on tertiary education (as a % of all levels) 1990	Public expenditure on tertiary education (as a % of all levels) 2000*	Tertiary students enrolled in science, maths and engineering (% of all tertiary students) 1998–2003
South Africa (Rep. of)	6.2	5.7	21.5	14.5	17
Gabon	–	3.9	–	25.5	–
Namibia	7.6	7.9	–	12.0	9
Botswana	6.7	2.1	–	18.6	19
Ghana	3.2	4.1	11.0	–	26
Cameroon	3.2	5.4	29.5	–	–
Togo	5.5	4.8	29.0	17.4	8
Congo	5.0	3.2	–	32.6	11
Lesotho	6.1	10.0	–	16.7	6
Uganda	1.5	2.5	–	–	8
Zimbabwe	–	10.4	12.3	–	–
Kenya	6.7	6.2	21.6	–	29
Madagascar	2.1	2.5	–	11.9	20
Nigeria	0.9	–	–	–	–
Gambia	3.8	2.7	17.8	–	–
Senegal	3.9	3.2	24.0	–	–
Rwanda	–	2.8	16.7	34.7	–
Guinea	–	1.9	–	–	–
Benin	–	3.3	–	16.4	25
Tanzania, United Rep.	3.2	–	–	–	22
Côte d'Ivoire	–	4.6	–	25.1	–
Zambia	2.4	1.9	–	–	30
Malawi	3.3	4.1	20.2	–	33
Angola	3.9	2.8	3.7	–	18
Chad	–	2.0	–	16.6	–
Ethiopia	3.4	4.8	12.1	–	19
Mozambique	3.9	2.4	9.9	–	–
Burundi	3.4	3.6	22.0	26.9	10
Mali	–	2.8	–	14.6	–
Burkina Faso	2.7	–	–	–	–
Niger	3.2	2.3	–	16.2	–

* For some countries, data may be for 1999 or 2001.

Source: Data provided by UNESCO Institute for Statistics in October 2005 and for: UNDP (2004) *Human Development Report.*

et al., *for doing;*

Table 5
PATENT APPLICATIONS FILED BY AND GRANTED TO AFRICAN COUNTRIES, 1999

	Applications filed		Patents granted	
	By residents	By non-residents	To residents	To non-residents
Algeria	34	248	0	0
Botswana	0	54	0	26
Egypt	536	1 146	38	372
Ethiopia	0	12	0	1
Gambia	0	7 903	0	26
Ghana	0	80 028	0	17
Kenya	28	80 516	3	91
Lesotho	0	80 315	0	43
Liberia	0	41 120	0	0
Madagascar	9	41 237	6	29
Malawi	1	80 430	0	84
Morocco	0	3 649	0	0
Rwanda	0	4	0	4
Sierra Leone	0	72 449	0	1
South Africa (Rep. of)	116	26 354	0	0
Sudan	2	80 424	0	0
Swaziland	0	40 673	0	57
Tanzania, United Rep.	0	14 467	0	0
Uganda	0	80 421	0	74
Zambia	5	87	0	66
Zimbabwe	1	80 167	0	34

Source: World Intellectual Property Organization.

WHAT PROSPECTS FOR AFRICA?

et al.

First, *develop, sustain and utilize local capacities and leadership in efforts to advance S&T.*

Six interdependent approaches

The 10 African national academies

Cameroon Academy of Sciences	Cameroon
Academy of Scientific Research and Technology (ASRT)	Egypt
Ghana Academy of Arts and Sciences (GAAS)	Ghana
Kenya National Academy of Sciences (KNAS)	Kenya
Académie Nationale Malgache	Madagascar
Nigerian Academy of Sciences	Nigeria
Académie des Sciences et Techniques du Sénégal (ASTS)	Senegal
Academy of Science of South Africa (ASSAf)	South Africa
The Uganda National Academy of Sciences (UNAS)	Uganda
Zimbabwe Academy of Sciences	Zimbabwe

Science makes a fresh start in Nigeria?

At the request of the Government of Nigeria, an international advisory board for the reform of the country's science, technology and innovation system was established by UNESCO in October 2004. A core activity of the reform programme is a joint review of investment, industry and innovation in Nigeria involving UNESCO, UNCTAD, UNIDO and WIPO. Financed in equal shares by the Government of Nigeria and UNESCO/Japan Funds-in-Trust to the tune of US$ 1 million, the review is part of preparatory work for a donors' conference Nigeria is planning to call to fund implementation of a multi-year plan of action on science, technology and innovation. Other international agencies expected to join the reform programme are the United Nations Economic Commission for Africa, the World Bank and the International Association of Universities.

Could science be making a fresh start in Nigeria? Since the transition to civilian rule in 1999, consolidated in 2003 with the election of the second Obasanjo government, Nigeria has certainly given signs of renewed interest in S&T. In October 2003, it launched a low Earth orbit remote-sensing micro-satellite to monitor the environment and provide information for infrastructure development. This prowess has enabled Nigeria to join a Disaster Monitoring Constellation grouping Algeria, China, the UK and Viet Nam.

President Obasanjo has since announced that his country is establishing, within UNESCO, a US$ 1 million Nigeria Special Funds-in-Trust for Science. This Special Fund will 'not only benefit Nigeria but also assist other African countries in designing project proposals for the reform of their national science systems and in developing managerial capacities', Nigeria's Minister of Science and Technology, Professor Turner T. Isoun stated in October 2004.

Nigeria has considerable human potential. It counts 60 universities, 44 polytechnics and 65 research institutes for a population of 133 million. However, there are also deep-rooted problems; these include insufficient funding of research and development, poor management, inadequate macro-level coordination and a lack of linkages between industry and research institutes or universities.

The need for reform is patent after four decades of military rule marked by state corruption and spiralling foreign debt, following independence in 1960. The rewards of reform could also be immense, for Nigeria is potentially a wealthy country. The world's 13th largest oil producer and the 6th largest in OPEC, Nigeria also has gas reserves which, when fully exploited, will place it among the world's top ten gas producers. However, 'in the 1980s, the country failed to use productively the oil windfall to improve social conditions and encourage the non-oil economic sector', writes the UK Department for International Development (DfID) in its Nigeria Draft Country Assistance Plan (2004). 'Between 1980 and 2000, Nigeria's per capita income plummeted to about US$290, well below the Sub-Saharan average of US$490.'

The reform comes at an auspicious time. After sluggish growth initially following the end of military rule, GDP rose by nearly 10% in 2003, driven by strong oil receipts and agricultural growth of 7%. Public spending has climbed markedly, from 19% of GDP in 1997 to 50% in 2001 (DfID). One aim of the science system reform will be to use this growth to diversify Nigeria's economy, in order to reduce the country's dependence on fluctuating oil prices: oil exports accounted for 95% of foreign earnings in 1998, compared with 58% in 1970 (UNDAF).

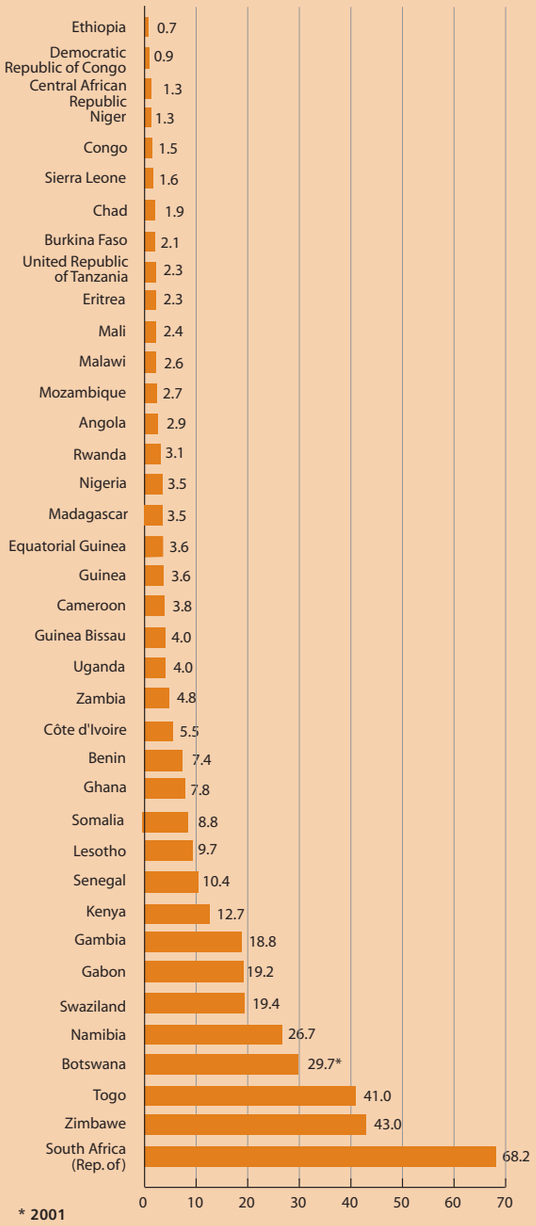
Second, *mobilize the best and most relevant S&T in Africa and elsewhere to address critical social and economic problems.*

IFS and TWAS support programmes in Africa

The International Foundation for Science (IFS) and the Academy of Sciences for the Developing World (TWAS) have supported many African scientists over recent decades: in sciences related to the management, conservation and sustainable use of natural resources for IFS and in the basic sciences, including biology, physics, chemistry and mathematics, for TWAS. Since 1974, IFS has supported some 1 250 African scientists in most African countries and TWAS close to 1 000 since 1986. As part of the Monitoring and Evaluation System for Impact Assessment (MESIA) being established at IFS, a tracer study of IFS grantees has been conducted in a selected number of countries including Cameroon, Morocco and the United Republic of Tanzania. Paradoxically, very few cases of true brain drain were found in the surveyed population. Out of 262 scientists surveyed some 30 years after the first grant was approved, only four had emigrated permanently to Europe and the USA. Most of the remaining scientists were still active in their respective countries except for the United Republic of Tanzania where some 10% were found to contribute to a regional circulation of scientists in Southern Africa. This shows that support well targeted to young scientists at the beginning of their research careers can be instrumental in retaining them in their national scientific communities.

See www.ifs.se and www.twas.org

Figure 4
SUB-SAHARAN INTERNET USERS PER 1000 POPULATION, 2002



* 2001

Source: http://unstats.un.org/unsd/mi/mi_series_results.asp?rowId=605

Third, *build a strong case at home and worldwide for supporting indigenous development of S&T.*

Fourth, *share innovative and successful experiences in the development and application of S&T.*

Fifth, *strengthen and build centres of excellence in Africa.*

THE ROAD AHEAD

NEPAD

The New Partnership for Africa's Development (NEPAD) was launched in 2001 as a comprehensive, integrated initiative for the revival and sustainable development of Africa. NEPAD is a programme of the African Union grouping 53 countries.

Within NEPAD, African statesmen are calling for greater investment in S&T. Were the target set by NEPAD in 2003 of devoting 1% of GDP to R&D within five years to be realized, it would constitute a mini-revolution for the African continent, where most countries devote less than 0.3% of the public purse to R&D.

It is not the first time that Africa's leading politicians have voiced their 'unflinching' support for such efforts. In 1980, there was the Lagos Plan for Action; in 1987, the Kilimanjaro Declaration; in 1988, the Khartoum Declaration; and, in 1998, the Addis Ababa Declaration. All called on sub-Saharan African nations to turn to S&T as primary sources of economic development.

What makes NEPAD's strategy different? First, the times. A steep decline in many economic and social indicators is a stark reminder that urgent action is needed now more than ever before. Second, the strategy lays heavy emphasis on human resources development as a prerequisite for science-based development and thus takes a long-range view of how progress should be defined and achieved. NEPAD emphasizes sensible goals and makes provisions for on-going evaluations and adjustments. Although the language may not be as dramatic as the statements associated with previous reform efforts, the prospects for success – albeit modest success – are greater. Third, NEPAD views the development of S&T as a tool rather than a goal, directly tying investments in S&T to such immediate needs as poverty elimination, improvements in public health, access to safe drinking water and environmental protection.

NEPAD's plan of action for S&T acknowledges that African science and scientists are currently cut off from the economic system. The plan of action consequently focuses on science policy development and flagship programmes that include biotechnology, indigenous knowledge and technologies, ways of developing university–industry partnerships, technology incubators, innovation hubs and training in science policy. This plan of action was adopted by a ministerial conference in Johannesburg, South Africa, in 2003, which in parallel established a Council of Ministers to serve as NEPAD's policy-making body.

NEPAD is encouraging both a dialogue between stakeholders in S&T and the elaboration of an appropriate regulatory and policy environment to nurture private investment in R&D. Regional centres of excellence are being promoted as a key strategy for boosting African collaboration. At the same time, NEPAD is fostering a genuine spirit of partnership which revolves around South–South and North–South collaboration. The Memorandum of Understanding signed in 2004 between NEPAD and the International Agricultural Research Centres of the CGIAR points in that direction.

See www.nepad.org

Future harvests today

The Consultative Group of International Agricultural Research (CGIAR) is a worldwide consortium of 15 research organizations, collectively known as the 'Future Harvest' institutions. Four of these research institutions, each with its own history of scientific excellence and specific mandate, are located in sub-Saharan Africa:

- Africa Rice Centre (WARDA), based in Bouakè, Côte d'Ivoire, has pioneered the development of Nerica (New Rice for Africa), which is expected to make Africa self-sufficient for rice by 2010.
- International Livestock Research institute (ILRI), based in Nairobi, Kenya, which works at the crossroads of livestock and poverty, bringing high-quality science and capacity-building to bear on poverty reduction and sustainable development for poor livestock keepers and their communities.
- International Institute for Tropical Agriculture (IITA), based in Ibadan, Nigeria, which focuses on crop management and improvement, especially for such small landholder crops as cassava, cowpea, plantain and yam.
- World Agroforestry Centre, based in Nairobi, Kenya, which conducts research on overcoming land depletion in the smallholder farms of the sub-humid and semi-arid regions of Africa, and searching for alternatives to slash-and-burn agriculture at the margins of the humid tropical forests.

The diverse mandates of these institutions – and the fact that other Future Harvest institutions based elsewhere are also collaborating to help solve some of Africa's agricultural problems – provide a network of scientific excellence. The reach of this network is extended through a host of regional centres distributed throughout sub-Saharan Africa that also assist in disseminating research results and 'best practices' to Africa's farmers.

See www.cgiar.org

acknowledging the full range of the problems facing science in Africa is just a first step.

history indicates that basic bread-and-butter issues often lose out to more glamorous visions of progress.

Sighting blindness

Just a decade ago, it was not uncommon for one in every three villages in parts of Burkina Faso, Ghana, Nigeria and other nations of sub-Saharan Africa to be afflicted with river blindness. Today, virtually no villages are. The progress that has been made in combating the disease represents one of the most triumphant public health campaigns ever waged in the developing world. But will this success continue? Nobody is sure. The reason for the concern is that the parasites causing the disease are likely to build resistance over time to the successful drug therapies that have been in put in place. For this reason, Thomas G. Egwang and his colleagues at the Med Biotech Laboratories at Makerere University in Kampala, Uganda, with the help of a grant from the Howard Hughes Foundation, USA, are seeking alternative treatments based on the medical community's rapidly advancing knowledge of molecular biology and, more specifically, biochemical pathways. Such knowledge could help researchers devise carefully targeted strategies designed to disrupt the disease-causing parasites' basic molecular functions. That, in turn, could serve as the basis for undermining the parasites' vitality and disrupting their reproductive cycles.

See www.mblab.or.ug

Models and mechanisms

African initiative

Launched in 1998 with financial assistance from the World Bank, the Millennium Science Initiative (MSI) strives to build capacity in modern science and technology in developing countries. To date, MSI institutes have been established in Brazil, Chile and Mexico, and have reached the implementation stage in Africa. With the aid of an African MSI task force, organized jointly by the Academy of Sciences for the Developing World (TWAS) and the Science Initiative Group (SIG), an independent non-governmental organization that advises the MSI, three priority areas have been selected: biology and biotechnology; mathematics; and instrumentation and information technology. MSI's strategy involves linking the work of local researchers, teachers and programmes to activities and institutions that are already in place.

Among the institutions acting as focal points for the initiative are Med Biotech Laboratories in Uganda; and the University of Dar es Salaam and the Tanzania Industrial Research and Development Organization (TIRDO), which are the primary nodes for the information technology and instrumentation facilities respectively. In contrast, the mathematics component is 'multi-centred', with hubs in such countries as Benin, Cameroon, Kenya and the Republic of South Africa.

See www.msi-sig.org

This chapter was prepared in 2001 and has been partially updated.

REFERENCES AND FURTHER READING

Arvanitis, R. (2001) Introduction. *Encyclopedia of Life Support Systems EOLSS. Section: Science and Technology Policy.* UNESCO, Paris.

Arvanitis, R. and Gaillard, J. (1992) *Science Indicators for Developing Countries*. Collection colloques et séminaires. Institut de recherche pour le développement, Paris.

Arvanitis, R., Waast, R. and Gaillard, J. (2000) Science in Africa: a bibliometric panorama using PASCAL database. *Scientometrics*, 47(3): p. 457–73.

Current Science (2001) Science in the Third World. *Current Science* 81, 25 October 2001, special issue, Bangalore, India.

Dahoun, M. (1997) *Le statut de la science et de la recherche au Bénin.* Logos-Verl., Berlin, 320 pp.

Davis, C.H. (1983) Institutional sectors of 'mainstream' science production in subsaharan Africa, 1970-1979: a quantitative analysis. *Scientometrics*, 5(3): p. 163–75.

Eisemon, T.O. (1979) The implementation of science in Nigeria and Kenya. *Minerva*, 12(4): p. 504–26.

Gaillard, J. (1994) North–South research partnership: is collaboration possible between unequal partners? *Knowledge and Policy*, 7(2): p. 31–63.

Gaillard, J. (1999) *La coopération scientifique et technique avec les Pays du Sud, peut-on partager la science?* Karthala, Paris.

Gaillard, J. and Furó Tullberg, Anna (2001) *Questionnaire Survey of African Scientists, IFS Grantees and INCO Beneficiaries.* IFS: MESIA Report No. 2, Stockholm, 90 pp.

Gaillard, J., Krishna, V.V. and Waast, R. (eds.) (1997) *Scientific Communities in the Developing World*. Sage, New Delhi and London, 398 pp.

Gaillard, J. and Waast, R. (1993) The uphill emergence of scientific communities in Africa. *Journal of African and Asian Studies*, 27(1–2): p. 41–68.

Gaillard, J. and Waast, R. (2000) L'aide à la recherche en Afrique subsaharienne: comment sortir de la dépendance? Le cas du Sénégal et de la Tanzanie. *Autrepart* 13: p. 71–89.

Hassan, M.H.A. (2000) Can science save Africa? *Science* 292 (1 June), p. 1609.

Hassan, M.H.A. and Schaffer, D. (2001) The Third World Academy of Sciences: celebrating two decades of progress. *Current Science,* 81, 25 October.

Kolinsky, M. (1985) The growth of Nigerian universities, 1948–1980. *Minerva*, 23(1): pp. 29–61.

Krishna, V.V., Waast, R. and Gaillard, J. (2000) The changing structure of science in developing countries. *Science, Technology & Society*, 5(2): pp. 209–24.

Lebeau, Y. and Ogunsanya, M. (eds.) (1999) *The Dilemma of Post-Colonial Universities.* IFRA/African BookBuilders, Ibadan.

Lebeau, Y., Onyeonoru, I. and Ukah, F.K. (2000) Nigeria country report. In: Waast, R.; Gaillard, J. (coord.) *Science in Africa at the Dawn of the 21st Century*. IInstitut de recherche pour le développement, Paris.

Mouton, J., Boshoff, S.C., Ravat, E. and Ravjee, N. (2000) Science in transition. In: Waast, R; Gaillard, J. (coord.) *Science in Africa at the Dawn of the 21st Century*. IInstitut de recherche pour le développement, Paris.

UNDP (2001) *Human Development Report 2001: Making Technologies Work for Human Development*. UNDP/Oxford University Press, New York–Oxford.

UNDP and TWNSO (1998) *Sharing Innovative Experiences: Examples of Successful Initiatives in Science and Technology in the South.* UNDP and Third World Network of Scientific Organizations (TWNSO), New York.

— (2001) *Sharing Innovative Experiences in the Conservation and Wise Use of Medicinal and Indigenous Plants.* HEJ Research Institute of Chemistry, Karachi, for UNDP and TWNSO, Karachi.

UNESCO (2000) *World Conference on Science: Science For The Twenty-First Century World: A New Commitment*. UNESCO, London.

Waast, R. (2001) Science and technology policies in Africa, *Encyclopedia of Life Support Systems EOLSS. Section: Science and Technology Policy.* UNESCO, Paris.

Waast, R. and Gaillard, J. (coord.) (2000) *Science in Africa at the Dawn of the 21st Century*. IRD, Paris.

World Bank (2000) *Higher Education in Developing Countries: Peril and Promise*. World Bank, Washington DC.

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A trained agricultural engineer with a doctorate in science, technology and society, he has published over 30 papers, six books as author and six books as editor in his field.

Mohamed H.A. Hassan is Executive Director of the Third World Academy of Sciences (TWAS), President of the African Academy of Sciences (AAS), Secretary General of the Third World Network of Scientific Organizations (TWNSO) and serves on a number of committees in other organizations worldwide.

He holds a PhD in plasma physics from the University of Oxford, UK (1974). A former professor and dean of the School of Mathematical Sciences at the University of Khartoum, he received the order of scientific merit of Brazil. He is a fellow of TWAS, AAS and the Islamic Academy of Sciences as well as honorary member of the Colombian Academy of Exact, Physical and Natural Sciences and corresponding member of the Belgian Royal Overseas Academy of Sciences. His research areas include theoretical plasma physics, physics of wind erosion and sand transport.

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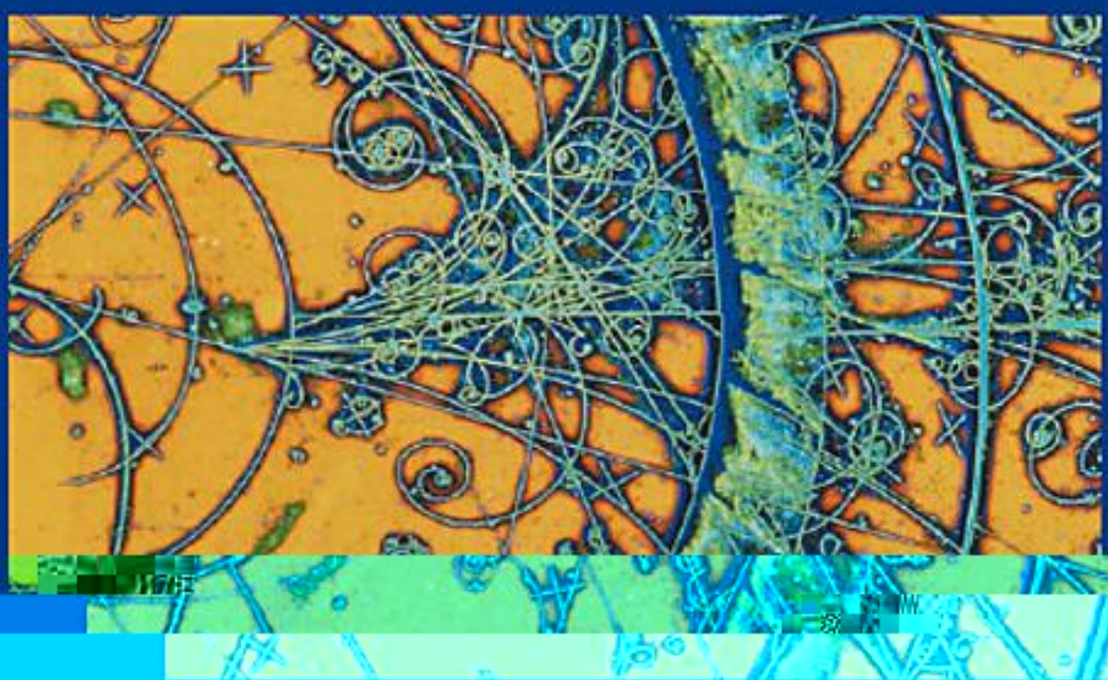

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