Multilateral Initiative on Malaria

Strengthening Health Research in the Developing World

Malaria Research Capacity in Africa

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Preface

Despite nearly a century of research, malaria has yet to be conquered in its bastion, Africa south of the Sahara, where the majority of the world's cases are to be found. Nevertheless, the tremendous effort to understand the disease and develop effective methods of control has removed the disease from significant parts of the world.

A major component of the research effort against malaria is the capacity of scientists based in Africa to study the disease on the ground. This report identifies existing centres of excellence as well as highlighting areas of remaining need. As is typical of reports of this kind, in which new data are brought to the fore, interesting phenomena are uncovered which, when revealed, suggest obvious solutions. Perhaps the best example of this is that the majority of collaborations that individual scientists in Africa have are with laboratories outside the continent, mainly Europe and the USA. Surprisingly, there is minimal collaboration within Africa. Therefore, funds need to be made available to foster collaborations on the continent and maximize the impact of existing knowledge and experiences.

Although the objective of this report was to provide evidence to guide the development of the Multilateral Initiative on Malaria, its findings can probably be generalized to many areas of health research. Clearly, further coordination of the multitude of agencies supporting health research is called for, but perhaps more importantly there needs to be a closer link between these agencies and scientists to identify local needs as well as with governments to ensure the long-term sustainability of the research infrastructure. It is very much hoped that this report will stimulate such activities in an analogous manner to an earlier report on malaria research from the same stable.

Richard Lane
Head of the Wellcome Trust's International Programmes

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Glossary of abbreviations and acronyms

AusAID	Australian Agency for International Development
BADC	Belgian Administration for Development Cooperation (Administration Générale de la Coopération au Développement)
BMZ	Ministry of Economic Cooperation and Development
BWF	Burroughs Wellcome Fund, USA
CDC	Centers for Disease Control and Prevention (USA)
CIDA	Canadian International Development Agency
CNPq	Conselho Nacional de Desenvolvimento Científico e Tecnológico, Brazil (National Council for the Development of Science and Technology)
COHRED	Council on Health Research for Development
DAAD	Deutscher Akademischer Austauschdienst (German Academic Exchange Service)
DANIDA	Danish International Development Assistance
DBL	Danish Bilharziasis Laboratory
DEA	Diplome d'Études Approfondies
DFG	Deutsche Forschungsgemeinschaft
DFID	UK Department for International Development (formerly ODA)
DOD	US Department of Defense
DG XII	Directorate General XII, European Commission
EIS	Epidemic Intelligence Service
ENRECA	Enhancement of Research Capacity in Developing Countries, DANIDA
FCS	Federal Commission for Scholarships for foreign students, Switzerland
FIC	Fogarty International Center, US National Institutes of Health
FINEP	Financiadora de Estudos e Projectos (Brazilian Agency for the Funding of Studies and Projects)
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (German Agency for Technical Cooperation)
HRP	UNDP/UNFPA/WHO Special Programme for Research, Development and Research Training in Human Reproduction
IAEA	International Atomic Energy Agency
IDRC	International Development Research Centre, Canada
IHTM	Institute of Hygiene and Tropical Medicine, Portugal
INCLEN	International Clinical Epidemiology Network
INCO-DC	International Cooperation with Developing Countries programme, European Commission
INPA	Instituto Nacional de Pesquisas da Amazonia (National Amazon Research Institute), Brazil
INSERM	Institut National de la Santé Recherche Médicale (French Institute of Health and Medical Research)
IRD	Institut de Recherche pour le Développpment (formerly ORSTOM), France
IRTC	WHO Immunology Research and Training Centre, Lausanne, Switzerland
JICA	Japan International Cooperation Agency
KEMRI	Kenyan Medical Research Institute
MCT	Ministerio da Ciencia e Tecnologia (Ministry of Science and Technology), Brazil
MIM	Multilateral Initiative on Malaria
MRC	Medical Research Council (UK or South Africa)
NGO	Non-governmental organization
NIAID	National Institute of Allergy and Infectious Diseases (USA)
NIH	National Institutes of Health, USA
NORAD	Norwegian Agency for Development Cooperation
NRF	National Research Foundation, South Africa
OCEAC	L'Organisation de Coordination pour la Lutte contre les Endémies en Afrique
PAHO	Pan American Health Organization Regional Office of the World Health Organisation
RCS	Research Capability Strengthening
RTG	Research Training Grants
SAREC	Swedish Agency for Research Cooperation with Developing Countries
SCI	Science Citation Index
SDC	Swiss Agency for Development and Cooperation
SEAMEO–TROPMED	South East Asian Ministers of Education Organization Regional Tropical Medicine and Public Health Network
Sida	Swedish International Development Cooperation Agency
SNSF	Swiss National Science Foundation
STI	Swiss Tropical Insitute, Basle
TCP	Technical Cooperation Projects
TDR	UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases
UNDP	United Nations Development Programme
UNFPA	United Nations Population Fund
UNICEF	United Nations Children's Fund
USAID	US Agency for International Development
WHO	World Health Organization
WRAIR	Walter Reed Army Institute of Research, US Department of Defense

Executive summary

INTRODUCTION

Experiences during the last century have shown that the returns from well-targeted health research can be immense. Vaccines and disease treatments, for example, together with new knowledge to enable people to maintain their own health, have averted disease, reduced suffering and enabled greater productivity in many regions. However, the research bases in most developing countries require significant strengthening to enable effective responses to the challenges of local health problems.

The Multilateral Initiative on Malaria (MIM) is a global initiative that is particularly concerned with building research capacity in Africa to tackle the major and increasing problem posed by malaria. This study was undertaken by the Wellcome Trust as part of the activities of MIM. The purpose was to generate sound analytical data that could inform discussions on strategies for strengthening research bases in Africa and enable future monitoring of progress.

The study included a unique survey of training opportunities in health and biomedical research offered by high-income countries to scientists in developing regions. It also examined the current status of malaria research capacity and training in Africa using a number of approaches. Research outputs, infrastructure, availability of trained personnel, training pathways and funding sources were assessed, and the opinions of African scientists on training needs and solutions were sought.

The findings of the review represent a resource for funding organizations and governments in both developed and developing countries to assist evidence-based approaches to research training activities. In addition, the report is intended to raise awareness amongst African scientists of current research training opportunities and the characteristics of leading malaria research centres across sub-Saharan Africa. Although the review has a particular focus on malaria research in Africa, many of the conclusions are more broadly applicable to capacity development in other research areas and other developing regions.

MAIN ELEMENTS OF THE STUDY

The study comprised the following analytical approaches:

1. A survey of training opportunities for developing-country scientists in biomedical sciences and health offered by funding organizations internationally (1995–98).
2. An assessment of research capacity and training activities in African malaria research through:
   - analysis of malaria publication outputs in MEDLINE and Science Citation Index (SCI) databases (1995–97) to identify the most productive countries and centres, collaboration patterns, funding sources, subfield specializations and citation impact;
   - analysis of research literature cited in African national malaria treatment guidelines and policies;
   - a questionnaire-based survey of 54 malaria research centres across Africa to assess facilities, expertise and training pathways, and to gather opinions on research training needs and solutions.

MAIN FINDINGS

Broad indicators of malaria research capability

Analysis of malaria publications in the SCI database for 1995–97 showed that African scientists and institutes make a major contribution to international malaria research: 17.2 per cent of global publications included an address in Africa. By comparison, the contribution of Africa to overall research in health and biomedicine, stands at just 1.2 per cent of the world's output. The highest contributing individual countries in malaria research were the USA, UK and France which participated in 30.0, 17.8 and 9.6 per cent of publications respectively in the three-year period assessed.

Malaria research is a strong component of all research relevant to health or disease in developing countries, representing an estimated 21 per cent of worldwide publications in tropical medicine. However, the absolute level of malaria research activity is low relative to other areas of biomedical research and in relation to the global burden of malaria disease: publications numbered approximately 1000 a year and accounted

for just 0.3 per cent of all outputs in SCI annually. By comparison, cardiology accounted for 10.2 per cent, and arthritis and rheumatism 2.4 per cent of world SCI publications in 1995. The low publishing activity in international malaria research reflects the relatively small global investment, which stood at about US$100 million in 1998.

Kenya, Tanzania, Nigeria and The Gambia were the highest publishing African countries in malaria research in 1995–97, each producing more than 50 papers. The most productive individual research programmes were located at the UK Medical Research Council Laboratories, Fajara, The Gambia; the KEMRI–Wellcome Trust collaborative programme in Kilifi and Nairobi, Kenya; and the University of Ibadan, Nigeria. Seven centres published more than 20 papers in the three-year period assessed.

Overall, African malaria research publications show extensive international co-authorship: 79 per cent of papers were found to involve collaboration outside Africa, particularly with Europe and the USA, and few linkages across Africa were observed. While this high degree of collaboration indicates productive links between laboratory research in 'Northern' laboratories, and field and clinical studies in Africa, it also reflects dependence on foreign funding sources and on external expertise.

Direct survey of African malaria research laboratories provided a more detailed impression of the availability of human resources for research and revealed the presence of a core of trained scientists currently engaged in malaria research. A total of 752 malaria researchers trained to at least first degree level were identified in 54 research centres across sub-Saharan Africa. A high proportion (35 per cent) were trained to Master's level, while postdoctoral scientists and clinicians were also well represented (26 and 22 per cent respectively). The majority of PhD graduates held Master's degrees and nearly half of clinical researchers also held higher degrees. However, the 192 postdoctoral and 168 clinical scientists identified were dispersed across 22 countries so that the numbers of trained researchers per country were small. In addition, about one-third of research groups were led by non-national scientists. Of the 313 individual questionnaire respondents, 15 per cent were non-African. The results, therefore, indicate a strong need for additional African scientific leaders who are able to conduct innovative and independent research, and play a key role in capacity-building efforts.

While numbers of trained personnel and publications provide an indication of the level of research activity, they are unable to measure the impact and usefulness of that research. Citation indices of publications are commonly used measures of research impact, which indicate the influence of published results on the scientific community. African malaria research papers for 1995–97 had a lower potential citation impact than the international set of malaria papers for the same period. However, the result primarily reflects the highly clinical and applied nature of African research, as this type of research is known to attract fewer citations than more fundamental studies. Citations, therefore, do not provide an accurate measure of the value of more applied research, and alternative methods are required.

Literature cited in national guidelines and policies for the treatment and control of malaria from 11 African countries were examined to assess links between research and policies. The results indicated that it is clinical and in-country research, often recorded in grey literature, that influences policies rather than basic research. These observations would support investment in the local research bases in developing countries, particularly in clinical and applied sciences. Analysis of national policies and guidelines is an important potential method of demonstrating specific outcomes from clinical and applied research. However, there was a lack of a systematic approach to citing scientific literature in the documents examined, and more widespread use of this approach would be dependent on countries including full bibliographies in their policy documents.

Investments in research and training in developing regions

A diverse set of funding organizations in industrialized countries support research and training in Africa, Asia and South America, as revealed by surveys of funding agencies and of malaria research laboratories in Africa, and by analysis of funding acknowledgements on malaria publications. These include governmental, non-governmental and commercial sources.

The most frequently acknowledged funders on African malaria research publications were the UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR), the Wellcome Trust, the Kenyan Medical Research Institute (KEMRI) and the UK Medical Research Council. Commercial funding sources for African malaria research were not prominent: only Hoffman La Roche registered more than ten acknowledgements on publications over a three-year period. Fourteen commercial companies were listed in the survey of African research centres as providing grants, but funding was generally on a small scale.

Survey of funding organizations and of African malaria research laboratories indicated that training opportunities for developing-country scientists are widely dispersed across many organizations from high-income countries. However, only a few funders provide substantial levels of support, notably the Japan International Cooperation Agency (JICA), the European Commission (INCO-DC), the US National Institutes of Health (NIH), and TDR. Other relatively prominent direct supporters of training (excluding multilateral contributions) include Australian, Belgian, Danish, French, Swedish, Swiss Government agencies, the International Clinical Epidemiology Network (INCLEN) and the Wellcome Trust.

An aggregate expenditure by industrialized countries of US$261 million for training developing-country scientists in biomedical science and health was identified for the three-year period 1995–97. This figure is low when compared with the figure of US$145 million invested in a single year (1997) in developing biomedical research expertise in the UK. Nevertheless, there appears to be a growing international commitment to strengthening research capacity in developing countries: a 41 per cent increase in expenditure by high-income countries was observed over the three-year period assessed.

Contributions to training by governments in developing regions were not broadly surveyed, but data were obtained from Brazil and South Africa, which are by far the highest investors in research in their regions. The figures obtained suggest that expenditures by other countries in South America and sub-Saharan Africa are likely to be very low.

The research base in Africa is strongly dependent on external investment: 88 per cent of malaria research grants to African laboratories for 1993–98 were from organizations outside Africa. For PhD training, 65 per cent of funding acknowledgements were to agencies from developed regions, and 17 per cent to African governmental or local sources. Many researchers reported funding their own degree studies. African governments contribute significantly to support for Bachelor's degrees (over half in the group analysed), and to salaries of national researchers (68 per cent of survey group). Local government sources were also the highest individual category acknowledged for PhD and Master's training.

Career progression opportunities in biomedical research

Survey responses from 39 funding organzations revealed the broad range of training schemes in health and biomedical research offered by higher-income countries to scientists in developing countries. However, these training opportunities are generally dispersed, with many funders providing small numbers of awards annually. Training is often associated with specific programmes and is not offered openly, thus limiting options for individuals seeking to identify sources of funding. Relatively small numbers of organizations actively monitor the numbers and success of training awards, illustrating the lack of a coherent international approach to training scientists. Despite the large number of training schemes overall, there are few opportunities for scientists to develop their careers through the funding schemes of a single organization, as many funders target training at one level.

Most agencies focus their resources on particular regions, and available data suggested that Africa and Asia are slightly favoured over South America in terms of training opportunities.

The availability of international awards for developing-country scientists at different stages of career progression was assessed. It was found that:

- Training attachments in overseas laboratories and short courses are the most frequent types of support provided by organizations in developed countries, and accounted for a large proportion of overall identified expenditure.
- Very few organizations in high-income countries provide support for Bachelor's degrees.

- A large proportion (74 per cent) of organizations surveyed provides support for Master's training, although many provide only small numbers of awards annually. Over half of the identified Master's awards came from INCLEN and the Belgian Agency for Development Cooperation, and these awards were focused in the areas of clinical epidemiology, public health and related disciplines, indicating that the availability of Master's training in other disciplines is more limited.
- A smaller proportion of funders offers PhD training (just over half of those surveyed), but over 90 per cent of identified awards were provided by the European Commission, TDR, US National Institutes of Health (NIH) and DANIDA. AusAID is an important supporter of training for Asian scientists, although available data were incomplete. Survey of African research centres also identified L'Institut de Recherche pour le Développement (IRD) and the French Ministry of Cooperation as notable funders of PhD training.
- Postdoctoral training is often provided in association with larger research programmes and few agencies provide opportunities for individual postdoctoral scientists to apply for independent research support. The US NIH and the Wellcome Trust were the most prominent supporters of postdoctoral training identified in the survey. African scientists commented on the lack of availability of research awards to develop the careers of postdoctoral scientists.

The survey of funders from high-income countries identified a total of 684 PhD awards and 821 Master's awards for 1995–98. By comparison, in a single year (1997) there were an estimated 2101 PhD awards directed towards building biomedical research expertise in the UK, a country with a population of about one-seventy-fifth of the developing-country regions combined. This is equivalent to nearly 1000 times more PhD opportunities in the UK than in the developing regions, relative to population size. In view of the dependence of many developing countries on external funding sources for postgraduate training, the overall conclusion is that provision of research training opportunities for developing-country scientists is low relative to opportunities in industrialized countries.

These figures must of course be considered in the light of the more limited availability of graduates to absorb training at higher-degree levels in developing countries. However, comparative figures for numbers of tertiary students and PhD awards per unit population in developing and developed countries support the view that current PhD training in many developing countries is restricted. In addition, three-quarters of scientists in Africa responding to the MIM survey highlighted the need for additional opportunities at Master's and PhD level.

Training mechanisms and infrastructure

Most funding organizations link training to major research programmes that have received support through a competitive, peer-reviewed process, thus providing some assurance that training will take place in a strong intellectual environment. Funders also tend to focus resources on specific centres to develop facilities and a critical mass of people that will encourage high-quality science to flourish.

The survey of African malaria researchers revealed that 90 per cent of Bachelor's degrees had been completed within Africa (81 per cent locally or self-funded), but just over half of postgraduate qualifications had been obtained wholly or partially outside the home country. External training occurred most frequently in Europe followed by the USA. The extent of overseas training varied among countries, with more researchers receiving PhD training at home in Nigeria, South Africa, Cameroon and Senegal.

Patterns of African scientific partnerships and training sites are strongly moulded by funding mechanisms, which reflect historical and language associations and geographical proximity. In many cases training is offered in the country in which the donor organization is based. There are few funding mechanisms that support linkages between countries within developing regions. For example, France and the UK focus their resources primarily on centres in Francophone and Anglophone Africa respectively, contributing to a lack of interaction between institutes in these regions.

African survey respondents recognized the value of international partnerships as a mechanism for training and for technology transfer. They considered overseas training attachments to

be important in exposing developing-country scientists to the scientific culture and facilities of overseas centres of excellence. However, they also noted that overseas training is not always relevant to the home research base, is expensive, and may result in researchers being attracted permanently away from their home countries to locations where the facilities and career prospects are advantageous. It was considered that local training opportunities within Africa are not being fully exploited, and further investment in African training centres would be valuable to allow regional technology transfer and sharing of resources. Funding agencies are increasingly recognizing the benefits of using local and regional training facilities, combined with shorter training attachments in European or US laboratories, to develop sustainable and locally relevant research expertise.

Many of the most productive malaria research centres in Africa receive long-term support from external funders and are relatively well equipped, thus underscoring the importance of a stable foundation from which to develop an effective research programme. Over 90 per cent of all African malaria laboratories surveyed had core laboratory facilities (freezers, centrifuges, incubators and microscopes). However, a high proportion of individual survey respondents cited lack of research funds or poor infrastructure and laboratory facilities as major obstacles to developing a research career in Africa. African researchers also emphasized the critical importance of good communication links in allowing them to participate effectively in international research activities. The survey results indicate that the communications revolution is successfully reaching Africa as 90 per cent of laboratories had e-mail connections. The quality of electronic communications, however, was not assessed.

Adequate remuneration is a major factor in successfully retaining scientists in developing countries. Nearly 70 per cent of African scientists surveyed received their salaries from local sources, but many commented that these salaries were insufficient.

The present study identified the location and specializations of a number of strong malaria research centres across sub-Saharan Africa. Primary funding sources of these centres and international scientific partnerships have also been analysed. This information should assist both researchers and funders in identifying centres which might be further developed for local and regional training, and for multicentre studies.

Research specializations: diseases and disciplines

Research training schemes must aim to build capacity that is appropriate to national health needs and priorities. Many funding agencies target resources on particular diseases or disciplines. For example, INCLEN focuses on developing expertise in clinical epidemiology, and related disciplines, while WHO/TDR focuses on eight target tropical diseases. Training is also often linked to larger research programmes, whose research focus will strongly influence the balance of expertise generated by training activities. There is a need for overarching mechanisms to match capacity development to research priorities.

The major focus of current malaria research in Africa is on clinical studies, epidemiology, intervention trials and health services research. Only 3 per cent of African malaria publications in SCI and MEDLINE (1995–97) related to basic science studies of the malarial parasite, and 7 per cent to fundamental studies of mosquito vectors, or vector taxonomy, ecology or behaviour. Eighty-one per cent of African publications reported studies involving human subjects, compared with 46 per cent for malaria papers internationally. Direct survey of malaria research laboratories in Africa confirmed the strong presence of expertise in clinical and field-based research: for example 132 scientists trained in public health and 88 in epidemiology were identified. The results also suggested that facilities and expertise in molecular biology, biochemistry and immunology are increasing (gel electrophoresis and PCR equipment was present in 76 and 58 per cent of laboratories respectively). There appeared to be a lack of expertise in biostatistics, sociology and economics: 37, 36 and 12 individuals, respectively, were identified with training in these disciplines.

RECOMMENDATIONS FOR THE WAY FORWARD

This report has gathered information from different perspectives on the availability of training opportunities for scientists in developing countries, and on the current status of human and infrastructural resources for malaria research in Africa. In view of the enormity of the challenge in strengthening research capacity in developing countries, funding organizations and governments face some difficult decisions on where best to direct their resources for maximal effect. The results of this review point to a number of areas of weakness in current international research training activities and to specific conclusions relating to malaria research in Africa. The key points are summarized here together with recommendations for consideration by the Multilateral Initiative on Malaria, by other coordinating bodies such as the Roll Back Malaria Project of WHO, and by individual funding organizations in the developed and developing worlds.

International investment and coordination in research training

➤The research bases in many developing countries are currently heavily dependent on foreign investment, but the success of any capacity-building activities is ultimately dependent on local commitment to scientific research. Funding organizations internationally and governments of developing countries must, therefore, work together to build sustainable research expertise to address clearly identified national health research priorities. Coordinated and long-term investment by both national governments and external funders is needed to improve infrastructure and facilities. More formalized, overt partnerships may be required for maximal effect.

➤Current training offered by higher-income countries to developing-country scientists is generally fragmented and inadequately monitored. Greater efforts are required to coordinate activities internationally and to monitor the effectiveness of training programmes in order to maximize the impact of resources in building a core of appropriately skilled scientists. This coordination role is one that might be played by the Multilateral Initiative on Malaria.

➤Science is a global activity and the migration of scientists to high-income countries is a problem that must be addressed in order to build sustainable research bases in developing countries. National research institutes must be able compete successfully to retain scientists against both overseas institutes and the local private sector. Serious consideration must be given by local governments to the provision of adequate salary structures to reward productive scientists. More external funders might also consider provision of salary supplements to scientists who compete successfully for research awards.

➤The aggregate expenditure by industrialized countries in training scientists in developing regions appears low relative to population in these regions, and relative to expenditure on training scientists in industrialized countries. This is particularly significant in view of the observed dependence of developing countries on foreign investment in research training. A small increase in the proportion of overall budgets committed by larger research and development organizations to research training could potentially have a substantial overall impact.

➤Accurate measures of the impact of clinical and applied research are required to provide data to support investment in this type of research. The analysis of research cited in health policy documents is a potentially effective method of assessing the influence of research in informing clinical practice or disease control strategies, but effective implementation is dependent upon the inclusion of full bibliographies in policy documents.

Career progression opportunities in biomedical research

➤The majority of African scientists complete Bachelor's degrees in their home countries. Universities in developing regions, therefore, have the responsibility of ensuring that Bachelor's degree curricula are of high quality, reflect national scientific needs and generate an interest in scientific research.

➤Current availability of awards for PhD and Master's training in many developing countries from both local and international sources is very limited, even after taking into consideration the lower numbers of graduates in developing as

compared with developed countries. Greater opportunities are likely to be beneficial in developing a critical mass of independent scientists.

➤The wider availability of grants and fellowships to support the research projects of individual scientists would provide an incentive for scientists to develop careers in research and may contribute to the development of key scientific leaders.

➤There is a relatively large overall investment by high-income countries in providing short training attachments in overseas countries, workshops and short courses. These training mechanisms are potentially important, but they must be appropriately targeted and monitored for maximal effect. There is a need for a more detailed analysis of the nature of current activities of this type.

Training mechanisms and infrastructure

➤Training patterns are strongly influenced by rigid funding mechanisms that often involve collaborations between specific high- and low-income countries. The establishment of more varied funding formats would enable greater diversity in international scientific partnerships for more effective use of top-class training centres, irrespective of their location. Mechanisms to support linkages within developing regions are also required to allow sharing of regional resources and expertise, perhaps through more formalized research and training networks and multicentre approaches.

➤A high proportion of scientists from lower-income countries is currently trained overseas. Greater investment in developing countries is required to establish top-quality local and regional training centres, which can play a role in building sustainable and relevant national research expertise. This approach would assist in building productive collaborations between neighbouring countries and may also prove to be more cost-effective in the long-term.

➤The balance of expertise generated by training is determined primarily by funding policies of individual agencies that target particular diseases or disciplines, and by the focus of large research programmes with which training is associated. There is a need for mechanisms, at national and international levels, to assess the overall distribution of training across different research areas and hence assist in mapping capacity development to national research priorities.

➤Stronger links between the research and control communities are required to facilitate orientation of research agendas to practical health needs, and to promote rapid uptake of research results into policy and practice.

Malaria research capacity in Africa

➤Malaria research is a particular strength of sub-Saharan Africa and the current study has identified and characterized the most productive research centres. These centres represent a strong base for the development of a network of sites for training and for multicentre studies.

➤A core of training African scientists engaged in malaria research has been established, but the numbers of trained scientists are relatively small overall and there appears to be substantial dependence on external expertise from Europe and North America. Continuing efforts are required to train African scientific leaders for the future.

➤African centres appear to lack expertise in health economics, social sciences, and biostatistics, and these disciplines may require specific strengthening in view of their importance in optimizing the delivery of healthcare and disease control interventions.

➤This review has provided baseline data on research activity, infrastructure and trained personnel which can be used to measure progress in strengthening malaria research capability in Africa.

Introduction 1

This report has been prepared by the Wellcome Trust as part of the activities of the Multilateral Initiative on Malaria (MIM). A major objective of this initiative is to strengthen and sustain malaria research in African countries through partnerships with scientists internationally. However, it was recognized early in the establishment of the initiative that very little information is available on current research capability in developing countries. Organizations involved in MIM agreed that such data were crucial to inform discussions on potential options for strengthening long-term research capability. Hence, it was decided that a review of current research training schemes should be carried out, together with an assessment of human and infrastructural resources for malaria research in Africa. The Wellcome Trust, as the coordinator of MIM during 1998 and a major funder of malaria research, undertook to carry out this study, drawing on experience from a previous review of international malaria research (Anderson *et al.*, 1996).

1.1 APPROACHES TO THE STUDY

The MIM review includes the following analytical approaches:

1. A survey of training opportunities in health and biomedical research offered by international funding organizations to scientists in Africa, Asia and South America.
2. An assessment of current malaria research capacity and training in Africa including:
   - analysis of African malaria research publications, in the context of global publications, to assess relative outputs of countries and institutes, collaboration links, subfield strengths and weaknesses, and funding sources;
   - analysis of journal impact factors for African malaria research publications to assess the potential influence of the reported research on the scientific community;
   - analysis of literature cited in African national malaria treatment policies to elucidate the research guiding policy formulation;
   - a survey of African malaria research laboratories to assess current research expertise, facilities and training pathways, and to obtain opinions on needs and solutions in capacity development in Africa.

Where possible, the study made use of pre-existing information contained within the Directory of the African Malaria Vaccine Testing Network (AMVTN)[1] and the 'Inventory of resources and activities' produced for the International Conference on Malaria, held in Dakar, Senegal, in 1997. However, the major part of the review presents novel bibliometric and survey information.

1.2 BACKGROUND

The quality and productivity of scientific research in the lower-income countries of the world currently lags far behind that of industrialized nations, and the lack of local research capacity has seriously hindered progress against health problems in developing regions. Estimates from the United Nations Educational, Scientific and Cultural Organization (UNESCO, 1996) suggest that Africa, Latin America and the Middle East together account for only 13 per cent of the world's scientists, with the majority being concentrated in the Western industrialized nations. There is, however, growing awareness of the need to strengthen indigenous research capacity to enable developing countries to respond to their own health challenges in a more effective and sustainable way (e.g. COHRED, 1990). Scientific research has had a dramatic impact in improving health this century in many regions of the world, through the development of new treatments and control interventions, and through providing knowledge to enable people to maintain their own health. Research has also brought economic benefits through averting disease and decreasing healthcare costs.

It has been estimated that about half of all funds for research relevant to developing countries comes from local governments, with the

[1] www.amvtn.org

remainder coming from external sources (Michaud and Murray, 1996). Successful strengthening of the science base in developing countries is therefore heavily dependent upon external investment. In view of the enormity of the challenge and limitations in resources, it is evident that inputs from organizations internationally need to be focused and coordinated in order to achieve maximal effect.

On a broad level there has been a recent move towards evidence-based approaches to research investments. Individual organizations are placing greater emphasis on evaluating their funding policies and assessing how their contributions integrate into an international context. There are also ongoing activities to analyse global resource flows into health research, that will facilitate rational investment in relation to disease burden estimates (e.g. the WHO Ad Hoc Committee on Health Research, 1996; and the Global Forum for Health Research, Geneva). In addition, initiatives such as the Multilateral Initiative on Malaria are providing a structural framework for coordinated international investments by scientific funding organizations.

Analytical data to inform decision-making on strengthening research in developing countries are not readily available. Comparative figures on human resources in different regions are difficult to obtain and highly incomplete (UNESCO, 1998). Some data specifically relating to malaria research capacity have been gathered previously, but these have not been subject to detailed analysis (e.g. AMVTN Directory and an Inventory produced for the International Conference on Malaria, Dakar, Senegal, 1997). Reviews focusing on research training have been limited in scope and have tended to focus on specific issues or schemes (e.g. Doumbo and Krogstad, 1998; TDR, 1999; INCLEN Internal Review, 1999). What is lacking is overview information on the extent and nature of international training schemes for scientists in developing countries, and the degree to which they provide a coherent training framework.

This study aimed to complement existing analytical efforts and to fill some of the gaps in currently available information. A large body of original data has been gathered and analysed, and the main findings are being published in this report as a resource for funding agencies internationally. While a major part of the report focuses on malaria research in Africa, many of the conclusions are of broader relevance to building research capacity in the poorer countries of the world. The data on current malaria research productivity also provide indicators to enable future monitoring of the success of programmes to train scientists in developing countries. Finally, and importantly, the report is directed towards developing country scientists themselves to raise awareness of current training opportunities and of the location of centres of malaria research expertise across the African continent.

1.3 HEALTH RESEARCH IN DEVELOPING COUNTRIES

Health problems in Africa and in other low- and medium-income regions remain a significant challenge: with the persisting burden of avoidable childhood and maternal diseases, a diverse and changing threat from infectious diseases, and a rapidly emerging epidemic from noncommunicable diseases and injury. Malaria is one disease in particular that continues to be a major problem, despite previous eradication campaigns (see below).

Overall, it is estimated that more than 90 per cent of the world's burden of preventable mortality occurs in low- and middle-income countries. Nevertheless, these health problems of developing countries receive relatively little attention, with most global resources being directed towards diseases of higher-income countries. Of the global investment in health research and development (about US$55 billion annually), only 5–10 per cent is thought to be devoted to health problems in low- and middle-income countries, (Michaud and Murray, 1996). There is a strong need, therefore, for a rational, coordinated international response to diseases of lower-income countries, which will contribute towards redressing this imbalance.

Within the context of international research activity, scientists working in developing countries have a critical contribution to make. A strong indigenous science base is required for countries to define and address their own health research priorities, thereby contributing towards improving health and towards social and economic development.

Investment in science in developing countries over the last 50 years has been successful in beginning to establish national scientific communities with internationally recognized scientific leaders. For example, financing of research in sub-Saharan Africa increased sevenfold in 1970–85 and the number of people engaged in research by a factor of ten (Gaillard and Waast, 1993). Despite this progress, developing countries still contribute only a small fraction of the world scientific publications: an estimated 6.5 per cent of the total (OST, 1997).

Across the developing nations there are regional and country-specific patterns and trends in scientific research. Figures derived from the Science Citation Index (SCI) and Compumath databases provide some indicators of scientific activity (UNESCO, 1998). Latin America accounts for about 1.5 per cent of scientific outputs in all disciplines, while sub-Saharan Africa accounts for 0.8 per cent, China 1.6 per cent, India and Central Asia 2.1 per cent and South-East Asia just 0.1 per cent. The world share of publications outputs from sub-Saharan Africa dropped by 19 per cent between 1990 and 1995, while the outputs from China and Latin America increased substantially (+38 and +17 per cent respectively) and the outputs from Asia remained relatively steady.

The different regions also have different disciplinary specializations: sub-Saharan Africa is strongest in applied biology/ecology and weakest in basic biology, chemistry, physics and engineering. Conversely chemistry, physics and engineering are relative strengths of China, India and Central Asia. Latin America is strongest in applied biology and ecology. It should be noted, however, that the databases used for these analyses are biased towards English-language journals and do not take into account local and regional journals that are particularly prominent in China and Latin America, and which might provide more accurate insight into locally relevant research capacity. The results, however, do give a fair representation of the broad international scientific visibility of the different regions.

Public investment in research and development (R&D) by developing countries is the lowest in the world, illustrating the lack of local resources to sustain scientific activity. Similarly, the available figures for trained scientific personnel in developing regions are also very low relative to industrialized countries.

The above data on scientific activity in developing countries are a strong indication that these regions remain ill-equipped to respond to the major challenges posed by local health problems such as malaria, tuberculosis, HIV/AIDS and upper respiratory tract infections.

1.4 PUBLIC HEALTH SIGNIFICANCE OF MALARIA

Malaria is a major and increasing cause of disease burden globally and is estimated to be responsible for more than one million deaths and almost 300 million clinical cases annually worldwide (See 'Rolling Back Malaria' in the WHO World Health Report, 1999). The disease has its greatest impact in sub-Saharan African where an estimated 90 per cent of cases occur, often in young children. The economic impact of malaria in Africa is substantial. Despite successes in controlling malaria in the 1950s and 1960s, recent years have seen a resurgence due to a combination of factors. There is growing resistance to current antimalarial drugs in many areas, including multidrug resistance. Increasing insecticide resistance, environmental changes and human migration, often the result of political instability and wars, are further contributory factors. A reduced commitment to control programmes in some regions has also had the serious consequence of exposing populations with decreased immunity to the threat of malaria.

Over the past few years there has been a growing momentum to address the problem of malaria. Strong international commitment has developed, and action has taken place in a range of different sectors. For example in Amsterdam in 1992, a Revised Global Malaria Strategy was approved by the health ministers of several malarious countries (WHO, 1993). This was followed in 1996 by discussions between the WHO Regional Office for Africa (AFRO) and the World Bank, leading to plans for a malaria control programme to be targeted at malarious areas across the African continent. At the same time, discussions were under way in the research arena to develop a more cohesive and coordinated international approach to scientific research against malaria, leading to the establishment of

the Multilateral Initiative on Malaria. Most recently, WHO, has recognized the impact of escalating mortality from malaria and announced a major new programme to 'Roll Back Malaria' (Nabarro and Tayler, 1998), which is global and aims to add value to and coordinate all efforts to control malaria.

1.5 THE MULTILATERAL INITIATIVE ON MALARIA

Origins and objectives

The Multilateral Initiative on Malaria (MIM) is an international alliance of organizations and individuals that aims to maximize the impact of scientific research against malaria. Enhancing coordination and collaboration, mobilizing resources, promoting capacity building in Africa, and encouraging research and control communities to engage in fruitful dialogues are major emphases of MIM.

The origins of MIM go back to a meeting held in 1995 between a number of organizations supporting scientific research in the developing world. From these discussions emerged a recognition that ongoing activities were fragmented with different organizations independently supporting research activities at various locations across the developing world. There was agreement that a mechanism was required to orchestrate these individual activities into a more coherent approach, which would have a stronger and more sustainable impact. Malaria in Africa was selected as an important focus to develop a mechanism to promote greater coordination amongst the range of different players; and so the concept of the Multilateral Initiative on Malaria (MIM) came into being. The original overarching goal was defined as "to strengthen and sustain through collaborative research and training, the capability of malaria-endemic countries in Africa to carry out research required to develop and improve tools for malaria control".

A defining step in the evolution of MIM was a congress convened in Dakar, Senegal, in January 1997 where the scientific community was asked to identify the major research questions that must be answered in order for the problem of malaria to be addressed effectively (Butler, 1997a; Mons *et al.,* 1998). The meeting was successful in highlighting specific research priorities, as well as some broad recurring needs that cut across different subject areas. The recommendations arising from this meeting have played a crucial role in guiding the activities of MIM. Follow up meetings during 1997 in The Hague (Butler, 1997b; Gallagher, 1997) and London (Butler, 1997c; Williams, 1997) then defined more clearly the areas for concerted action and set out the strategies for addressing priorities. At the London meeting, the Wellcome Trust accepted the nomination to act as a coordinator of the activities of MIM for an initial period of 12 months. One of the key priorities set at this meeting was to carry out a review of malaria research capacity in Africa. This priority, amongst others, was actively pursued by the Wellcome Trust, leading to the preparation of this report.

Key outcomes and future directions

MIM has been involved in a diverse range of activities since its establishment in 1997 (Davies, 1999). Importantly, the Initiative has played a significant role in drawing additional funds into malaria research: overall funds committed to malaria research increased from an estimated US$85 million in 1995 (Anderson *et al.,* 1996) to a figure of well over US$100 million in 1999.

MIM is particularly concerned with promoting global coordination and collaboration in the malaria research community to address scientific needs and opportunities. To this end, it has facilitated links not only between scientists, but also between the funding organizations supporting them. MIM meetings, newsletters and websites[2] have been important channels for enhancing communication amongst partners. Furthermore, the Malaria Foundation International has played a prominent role in raising awareness of the immense health and economic impacts of malaria.

There have also been unprecedented opportunities for interactions between scientists across Africa. The Dakar Conference in 1997 was a significant event in bringing together scientists from all regions of sub-Saharan Africa and, following the success of this meeting, MIM made a commitment to establish a regular forum of this kind. The first MIM African Malaria Conference took place in Durban, South Africa, in March 1999 and was attended by over 850 delegates. It was made possible through the gen-

erous sponsorship of a broad range of funding organizations and commercial companies. The Conference was successful not only in facilitating scientific collaborations across Africa and internationally, but also in strengthening links between the research and control communities.

MIM has also catalysed the establishment of formalized collaborations across Africa. Multicentre approaches can make a particular contribution by linking fragmented and isolated resources into networks which have the potential for much greater impact on malaria. Furthermore, single sites are not sufficient to obtain definitive answers in certain types of studies where large sample sizes are required, necessitating instead that standardized reagents and methodologies are applied at multiple sites. For example, a network linking five sites across Africa has been established to study severe malaria in children and particularly to evaluate novel treatments and develop new interventions.

To fulfil the need for standardized and well-characterized malaria research reagents identified in Dakar, a Malaria Research and Reference Reagent Repository has been established with funding from NIAID. This facility will maintain and distribute reagents such as parasite strains, mosquitoes, genetic material (e.g. DNA probes) and antibodies.

The immense opportunities offered to African scientists by electronic communications technology and the Internet have been recognized by MIM, and the US National Library for Medicine was nominated to lead an initiative in this area. Much improved connectivity has been achieved in Mali, and at two sites in Kenya, while plans for sites in Tanzania and Cameroon are advancing.

As part of its commitment towards building research expertise in Africa, MIM was responsible for the establishment of the new Task Force for Malaria Research Capability Strengthening in Africa, which is administered by the UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR) and is funded from several different sources. This Task Force provides support for research training in association with large multicentre studies across Africa.

Overall, MIM has helped to energize a new phase to improve approaches to international malaria research through creating new partnerships, and through providing a practical framework and point of reference to guide the activities of the international research community. The new working relationships established between the major funders are also having an influence in improving coordination in the broader field of biomedical and health research in the tropics. In the future MIM will continue to tackle key priorities, as well as bottlenecks impeding progress. It is also committed to working with the WHO Roll Back Malaria Project to ensure smooth integration of malaria research and control activities.

[2] www.wellcome.ac.uk/mim and www.malaria.org/mim www.mimcom.net

Training opportunities 2

This chapter presents the results of a survey of international research training opportunities in biomedical sciences and health for researchers in developing countries. The aim was to obtain an analytical overview of existing training schemes in order to assess the availability of support at different levels of training, in various disciplines, and across different geographical regions. Such data are essential to guide future directions in strengthening research capability in developing countries. The information should also be a valuable resource for scientists seeking support for research training.

2.1 METHODS

2.1.1 Survey of funding agencies

Funding agencies providing support for developing-country scientists were identified through literature searches, Internet searches and directories of grant-making organizations. The study focused primarily on funding organizations based in established market economies. Some information was obtained from governments of lower-income countries, although these sources of support were not broadly surveyed.

A questionnaire was sent to organizations requesting details of award schemes through which individuals from developing countries might receive funding. Information for the period 1995–98 was requested on:

- numbers of awards to developing-country scientists;
- expenditure on awards;
- training level of awards;
- the regional breakdown of awards into Africa, Asia and South America;
- proportion of awards for malaria research training.

As the questionnaire format was not necessarily compatible with the records kept, organizations were encouraged to submit as much relevant data as possible in a format convenient for their records. All organizations that contributed data were given an opportunity to check the accuracy of the presentation of their data in the report prior to its publication.

The following points should be noted:

- Although every effort was made to obtain comparable data, it cannot be assumed that all funding agencies classify their awards in the same way.
- Accurate figures for expenditure on training were sometimes difficult to identify where training was provided as part of a larger research or development programme.
- The review focused on organizations that administer training schemes and consequently funding agencies that contribute funds to secondary organizations for training may be less well represented in the review. Where possible, contributions from one organization to another are specifically stated and double counting of the funds avoided.

2.1.2 Data analysis

Expenditure totals were converted to US dollar equivalents using annual average exchange rates[1] for each of the years 1995 to 1997. Figures for 1998 were converted according to the exchange rate for June 30 1998. Expenditure was classified according to the financial year of the particular organization contacted. The specific time period covered in a financial year varies between organizations. Where the financial year spans more than one calendar year, the year assigned was that containing the greater proportion of the financial year. For example, the financial year of the Wellcome Trust runs from 1 October to 30 September, therefore FY 1995 refers to the period from 1 October 1994 to 30 September 1995.

Awards were classified according to the following categories:

- Bachelor's: undergraduate studies,
- Master's: postgraduate degree or studies, including Diplôme d'Études Approfondies;
- PhD: doctorate awarded for original research in a subject;
- postdoctoral: studies, research or professional work above the level of doctorate;
- training attachment: specific skills or technical training not necessarily leading to the award of a formal certificate. Training is often, but not always, provided at a research institute in a developed country;
- diploma: courses and specializations where a certificate is awarded.

[1] International Monetary Fund (1997) International Financial Statistics Yearbook, Vol. 50.

Awards were classified into three geographical regions: Africa, Asia and South America. Although several organizations supported research projects and training in Eastern Europe as part of their international programmes in health, these awards were excluded from the analysis. The review focused on research training opportunities and career progression in biomedicine and health. It should be noted, however, that in some instances it was difficult to separate research training from other more general types of training in health. The term 'developing-country scientist' is used broadly in this report to refer to laboratory and field-based researchers, health professionals, clinicians, sociologists, economists etc.

2.2 RESULTS

A total of 54 funding organizations were approached in the MIM survey and 39 organizations (74 per cent) responded with relevant information on research training activities for developing-country scientists in biomedicine and health. Of the responding organizations, 13 provided full data, 16 provided partial data and ten provided qualitative information. Respondents included governmental and non-governmental organizations, private foundations and international organizations (see Annex 2 for contact details).

The results are presented according to the geographical location of the organizations surveyed:

2.2.1 USA and Canada
2.2.2 Europe
2.2.3 Asia and Australia
2.2.4 International organizations
2.2.5 Developing countries

Within each section, organizations are classified as governmental or non-governmental. As far as possible, information is presented in a standardized format, although there is some variation according to the type of information provided by individual organizations. The headers in brown indicate the direct expenditure on training developing-country scientists unless otherwise stated.

2.2.1 USA and Canada

US Government

The Department of Health and Human Services (HHS) is the US Government's principal agency for protecting the health of all Americans and providing essential human services. There are eight Public Health Service Operating Divisions within the HHS. Two of the divisions, the National Institutes of Health (NIH) and the Centers for Disease Control and Prevention (CDC), have schemes of support for developing-country scientists.

US National Institutes of Health (NIH)

US$69.8 million in FYs 1995–98

The National Institutes of Health is the world's premier medical research organization whose mission is to uncover new knowledge that will lead to better health for everyone. The NIH budget for 1999 was US$15.7 billion. Within NIH, the Fogarty International Center (FIC) and the National Institute of Allergy and Infectious Diseases (NIAID) develop and administer research training programmes focused on developing countries. These programmes support research and training in a wide range of subjects including infectious diseases (with emphasis on HIV/AIDS, tuberculosis and malaria), environmental/occupational health, population-related issues, drug discovery and medical informatics. Table 2.1 shows the schemes of support offered by the FIC and NIAID that are open to scientists in developing countries and the expenditure per scheme in 1995–98. As well as these targeted schemes, NIH offers open grant programs to US snd non-US citizens.

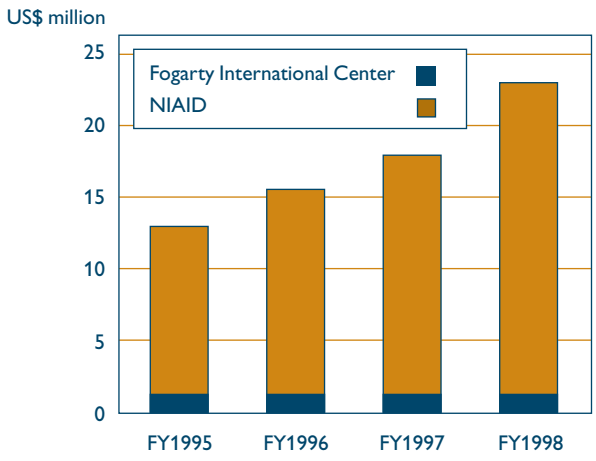
Expenditure by the FIC and NIAID on training developing-country scientists increased by 80 per cent in FYs 1995–98 (Figure 1). Within these training programmes, US$1.4 million (2 per cent of total) was devoted to malaria. The FIC and NIAID support training at all stages of career progression, but particularly at PhD and postdoctoral levels, and via training attachments (Figure 2). In general, academic

Table 2.1 The Fogarty International Center (FIC) and National Institute of Allergy and Infectious Diseases (NIAID) award schemes for scientists in developing countries.

Award scheme	Remit	Expenditure in 1995–98 (US$ million)	Year began
1 AIDS International Training and Research Program (AITRP)	Laboratory, clinical, epidemiological and public health aspects of HIV/AIDS	37.6	1988
2 International Cooperative Biodiversity Groups	Identification of novel therapeutics from indigenous flora and fauna; preservation of biodiversity	10.4	1993
3 International Training and Research Program in Emerging Infectious Diseases (ITREID)	Emerging infectious diseases (non-HIV/AIDS research)	8.1	1997
4 International Training and Research Program in Population and Health	Reproductive biology, and social and demographic correlates of fertility	4.9	1995
5 International Training and Research Program in Environmental and Occupational Health	Pollution (air, land and water) and occupational hazards	6.2	1995
6 Tuberculosis Training and Research Program	TB training (supplement to the ITREID and AITRP schemes)	1.1 (1998 only)	1998
7 International Training in Medical Informatics	Computer-assisted information processing and communications (focus on Africa)	0.6 (1998 only)	1998
8 Tropical Medicine Research Centre (TMRC)*	Awards to institutions in disease-endemic areas to support interdisciplinary research programmes on parasitic and other tropical infectious diseases	6	1990
9 International Collaborations in Infectious Diseases Research (ICIDR)*	Awards to support research partnerships between institutions in USA and disease-endemic countries	14	1979
10 Actions for Building Capacity	Research training in the context of specific scientific themes	Awards to be made in 1999	1999
11 Malaria research training	Malaria training (supplements to ITREID, AITRP and NIAID grants)	Awards to be made in 1999	1999

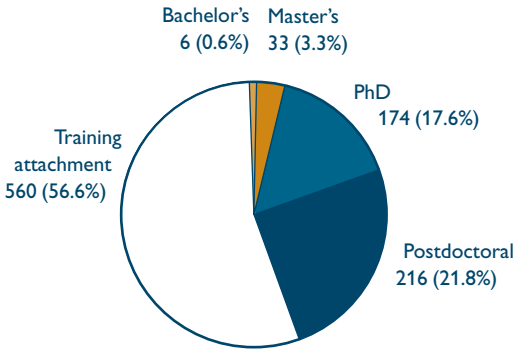
* NIAID administered schemes that primarily focus on research programmes, but include a training component (approximately 20 per cent of the programme budget). Programmes 1, 3, 5 and 6 have some activities in Eastern European countries, including the former Soviet Union.

Figure 2.1 Fogarty International Center (FIC) and National Institute of Allergy and Infectious Diseases (NIAID) expenditure on research training for developing-country scientists.



Total expenditure in FYs 1995–98 was US$69.8 million. These figures are restricted to training costs and exclude expenditure on major programmes of research through the ICIDR and TMRC awards (see Table 2.1)

Figure 2.2 Fogarty International Center (FIC) and National Institute of Allergy and Infectious Diseases (NIAID): Classification of support in FYs 1995–98 by training level and region.
Number of individuals trained = 989 (data for FY 1998 is provisional)



Number of individuals supported		
Africa	322	(32%)
Asia	284	(29%)
South America	383	(39%)

Table 2.2 The Fogarty International Center (FIC) and National Institute of Allergy and Infectious Diseases (NIAID) workshops in FYs 1995–98. (1998 data are provisional)

Region	Number of workshops	Number of participants
Africa	103	2735
Asia	50	1488
South America	244	23 838

training is conducted in USA and field research in disease-endemic areas. The FIC and NIAID also conduct training workshops in developing countries. In FYs 1995–98 nearly 400 workshops were organized, with over 28 000 participants from Africa, Asia and South America (Table 2.2).

Centers for Disease Control and Prevention (CDC)

CDC's mission is to promote health and quality of life by preventing and controlling disease, injury and disability. Its budget for 1999 was US$2.7 billion. CDC supports developing-country scientists in two ways:

- The Epidemic Intelligence Service (EIS). The EIS is a two-year postgraduate fellowship programme run by CDC for health professionals interested in the practice of epidemiology. During 1996–98, 17 developing-country scientists participated in the programme (Africa 5, Asia 5, South America 7).
- Training as part of CDC international research projects, principally at the field stations in Kenya (CDC/KEMRI) and Guatemala (MERTU/G). In Kenya, students may receive training at Master's and PhD level while working on CDC research projects. In Guatemala, the field station is an integral part of the Universidade del Valle de Guatemala. Undergraduates participate in research projects, and opportunities for training at Master's and PhD level exist. CDC has no dedicated award schemes for developing-country scientists and consequently expenditure on training varies according to the availability of research projects and the level of funding per project.

The US Agency for International Development (USAID)

USAID is the foreign assistance arm of the US Government. USAID supports applied research which includes biomedical, epidemiological, behavioural, economic and clinical research. The majority of research (80–90 per cent) is conducted in developing countries by national researchers.

USAID funds some developing-country institutions directly (e.g. the International Centre for Diarrhoeal Diseases Research, Bangladesh), but the majority of research is managed by a grantee institution which is usually US based, or by WHO. These institutions in essence operate small grants programmes. The cost and duration of support varies according to the research programme. The US-based funder normally plays the role of technical adviser and only participates in the research in a limited number of cases.

Capacity building is an important component of the research programmes with efforts focused on proposal development, workshops, short-term training in new methodologies and technologies, training in data analysis, and on developing skills for translating research results into policy and programmes. Networking and effective communication are also considered important components of the research. Both in-country and international networks have been fostered, the latter mainly through multi-country/multi-site intervention trials. Almost all research training at the postgraduate level is accomplished within the context of a research project. USAID expenditure on health research in total in 1995–98 was approximately US$158 million.

US Department of Defense – Walter Reed Army Institute of Research (WRAIR)

The WRAIR is the largest of six medical research laboratories under the US Army's Medical Research and Material Command. It is the US Department of Defense's lead agency for infectious disease research and a major source of research support for medical product development.

Training of developing-country scientists by WRAIR has an emphasis on antimalarial drug discovery and drug resistance, and vaccine development. Support is predominantly at postdoctoral level, through the National Research Council Associateship awards (funded by WRAIR) and funds from NIAID/FIC and WHO. Short research training attachments in malaria drug and vaccine development are also supported. In general, training is conducted at the WRAIR unit in Washington DC, USA, although opportunities for local training also exist in the six overseas laboratories in Brazil, Peru, Thailand, Indonesia, Egypt and Kenya. Table 2.3 shows the number of developing-country scientists trained by WRAIR in 1995–98.

US non-governmental organizations

The Burroughs Wellcome Fund

US$1.8 million on New Initiatives in Malaria awards in FYs 1996–98

The Burroughs Wellcome Fund (BWF) is an independent private foundation in the USA that was established in 1955 as a US extension of the UK-based Wellcome Trust. Its mission is to advance the medical sciences by supporting research and other scientific and educational activities, with emphasis on the career development of biomedical scientists and on advancing areas in the basic medical sciences that are under-funded or that have a shortage of qualified researchers. BWF spends US$30 million in grants annually in the USA and Canada. Opportunities for developing-country scientists exist through the New Initiatives in Malaria award scheme, although the majority of the US$1.8 million spent in FYs 1996–98 was directed to US-based researchers.

Table 2.3 WRAIR: Classification of support for 1995–98 by training level and region.

	Postdoctoral	Training attachment	Total	
Africa	8	8	16	(17%)
Asia	58	8	66	(72%)
South America	2	8	10	(11%)
Total	**68 (74%)**	**24 (26%)**	**92**	

These figures exclude trainees at WRAIR supported by fellowships from WHO and FIC/NIAID.

International Clinical Epidemiology Network (INCLEN)

US$4.9 million in FYs 1995–98

INCLEN is an independent non-profit organization established in 1980 which is dedicated to improving public health, by promoting clinical practice based on the best evidence of effectiveness and the efficient use of resources. INCLEN's central funding is primarily from two donors, the Rockefeller Foundation and USAID, with additional support from various sources. INCLEN has training centres in Canada, USA and Australia, and regional clinical epidemiology training centres in Latin America, China, South Asia and India. INCLEN's total expenditure in FYs 1995–98 was US$17.6 million (the financial year of INCLEN runs from 1 July to 30 June and FY 1995 was used to refer to the period 1 July 1994 to 30 June 1995). Expenditure on training in FYs 1995–98 was US$4.9 million. This figure is restricted to the expenditure on personal support and training of developing-country scientists and excludes core support for INCLEN's training centres. The majority of INCLEN's training is at Master's level (Figure 2.3) in the disciplines of clinical epidemiology, biostatistics, health social science and clinical economics.

Takemi Program in International Health, Harvard School of Public Health, USA

The Takemi Program is a ten-month research programme that focuses on the problems of mobilizing, allocating, and managing limited resources to improve health. Financial support for the Program comes from various sources:

- the Japan Foundation for the Promotion of International Medical Research Cooperation, in collaboration with the Japan Ministry of Health and Welfare, the Japan Medical Association, and the Japan Pharmaceutical Manufacturers Association;
- the Carnegie Corporation of New York;
- the Merck Company Foundation.

Takemi Fellows are mid-career professionals from around the world, particularly from developing countries. Fellows carry out their research projects at Harvard, generally using data they bring with them. Projects are closely linked to action programmes and to the work of Fellows in their home country. During 1995–97, 22 Fellows from developing countries completed the Takemi Program (Africa 8, Asia 10, South America 4).

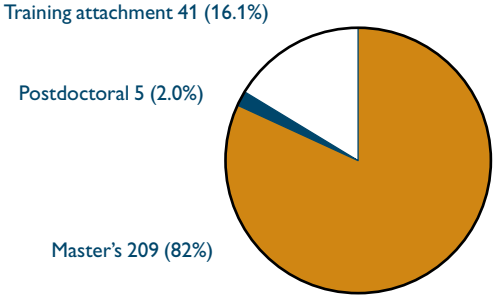
Canadian Government

Canadian International Development Agency (CIDA)

US$0.6 million in 1995–97

CIDA is the main organization involved in delivering Canada's official development assistance programme. Working with private and public sector partners in Canada and in developing countries, and with international organizations and agencies, it supports aid projects in developing countries. CIDA has no dedicated award schemes, but supports training as part of its international projects. CIDA's expenditure on health sector training in 1995–97 was US$0.6 million. This figure is restricted to

Figure 2.3 INCLEN: classification of support in FYs 1995–98 by training level and region.
Expenditure on training was US$4.9 million.
Number of individuals trained = 255



Number of individuals supported		
Africa	53	(21%)
Asia	98	(38%)
South America	104	(41%)

expenditure on training developing-country scientists and excludes project costs and the salaries of trainers, advisers and other health professionals working on CIDA's projects in developing countries.

During 1995–97, CIDA trained 76 individuals, mainly via training attachments in Canada (Figure 2.4). CIDA provides training for a variety of health professionals, including counsellors, nurses, clinicians and scientists.

International Development Research Centre (IDRC)

US$0.23 million in FYs 1995–98

The International Development Research Centre is a public corporation created by the Canadian Government to help communities in the developing world find solutions to social, economic and environmental problems through research. Developing-country scientists receive training as part of IDRC projects. In FYs 1995–98, IDRC supported three Master's students and three PhD students in biomedicine and health (Africa 5, South America 1). Training was conducted in Canada.

2.2.2 Europe

The Commission of the European Union

The European Union is composed of 15 European member states. Within the Union, the European Commission is the main executive body, with responsibility for three areas:

- initiating proposals for legislation;
- guardian of the treaties;
- management and execution of Union policies and of international trade relationships.

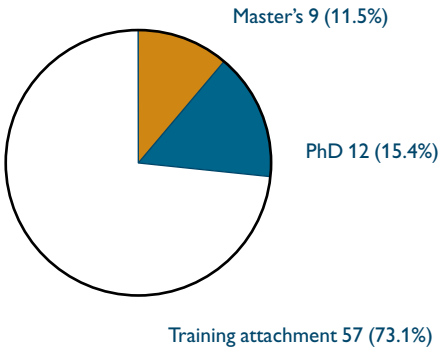
The Commission is divided into 26 directorates-general (DGs) with an additional 15 or so specialized services. Information on training was obtained from DG XII.

Directorate General XII (DG XII)

US$71.6 million on the INCO–DC Health programme in FYs 1995–98

DG XII has responsibility for Science, Research and Development. Within DG XII, scientists from developing countries receive training through the International Cooperation with Developing Countries programme (INCO-DC).

Figure 2.4 CIDA: Classification of support in FYs 1995–97 by training level and region.
Expenditure on training was US$0.6 million excluding project costs
Number of individuals trained = 78



Number of individuals supported		
Africa	24	(32%)
Asia	3	(4%)
South America	49	(64%)

This programme covers three main areas: natural resources, agriculture, and health. The total budget of the programme for 1995–98 was an estimated US$273 million. Each of the three areas receives similar levels of funding.

The programme promotes technological research and development in fields of relevance to developing countries through joint research activities with Europe, and aims to maintain and strengthen the research capacity of developing countries. Awards are partnership based and must include researchers from a minimum of two separate European member states (or associated countries) and at least one partner from a developing country. Training is an integral part of the programme and may be conducted in developing countries and/or Europe. During 1995–98, expenditure on the health programme increased fourfold (Figure 2.5). A total of 668 scientists from developing countries received training, mainly at PhD level and via training attachments (Figure 2.6).

Belgian Government

Belgian Administration for Development Cooperation (BADC)
Administration Générale de la Coopération au Développement, Belgium

US$8.8 million on scholarships and support to institutes in 1995–98

BADC supports development cooperation through governmental, non-governmental and multilateral mechanisms. Funds are allocated to several institutions for health research training:

- US$0.8 million per annum supports 44 scholarships for developing-country scientists to attend Master's courses in Disease Control, and Public Health at the Antwerp Institute for Tropical Medicine, Belgium;
- an annual award of US$0.5 million supports 20 scholarships for Master's courses in Public Health, and Health and Development at the Free University of Brussels, Belgium;

Fig. 2.5 European Commission INCO-DC: Annual expenditure on the health programme. Total expenditure in 1995–98 was US$71.6 million (not restricted to training). US$15.3 million (21 per cent of total) was on malaria

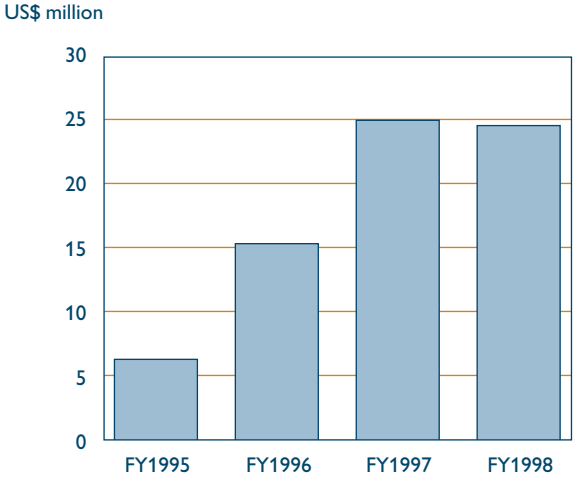
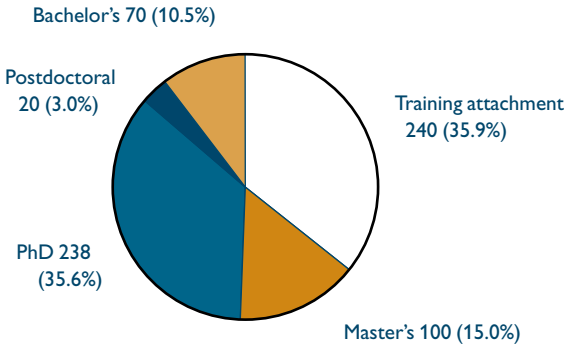


Fig. 2.6 European Commission INCO–DC Health programme: Classification of training in 1995–98 according to level. Number of individuals trained = 668



- the International Centre for Diarrhoeal Diseases Research, Bangladesh, receives an annual award of US$0.6 million for core financial support and research projects;
- the National Centre for Tropical Diseases, Bolivia receives an annual award of US$ 0.3 million for health projects and training.

The total number of master's awards in 1995–98 was 256. In addition, BADC funds training through its health projects in Africa, Asia and South America. Courses on a range of tropical diseases, including malaria and tuberculosis, are held regularly in developing countries.

Danish Government

Danish International Development Assistance (DANIDA)

DANIDA supports collaborative research with developing countries and training of developing-country scientists through several channels:

- The programme for Enhancement of Research Capacity in Developing Countries (ENRECA) aims to strengthen research capacity in developing countries through partnerships between Danish universities and research institutions, and institutions in developing countries. The programme covers a range of disciplines in agriculture, medicine and health, technology, social and natural sciences. Projects have a duration of 10–15 years and typically include postgraduate training of developing-country researchers, exchanges of research staff, provision of research equipment, and improvement of research infrastructure and communications. There have been four ENRECA-supported malaria projects in Africa since the programme's inception in 1988: Ghana, Mozambique, Tanzania and Sudan.
- The Danish Bilharziasis Laboratory (DBL) is a private institution involved in training, research and technical cooperation. It receives the majority of its funding from DANIDA. African researchers receive support through a Collaborative Award scheme for defined research or research training projects conducted in the home country with collaborative assistance and training from DBL. During 1995–98, 43 Master's and 92 PhD students were trained via the scheme, which has an annual budget of US$1.5 million.
- The Danish Council for Development Research supports three- to four-year collaborative projects with developing countries, where part of the research is conducted in the developing country.
- Contributions to TDR. The Danish government is a major contributor to the TDR programme, having donated US$26.3 million during 1989–98 (see Annex 1).

French Government

The French Government, in addition to its direct support to Institut de Recherche pour le Développement (IRD), Institut National de la Santé et de la Recherche Médicale (INSERM) and Institut Pasteur, provides funds via the Ministry of Cooperation for French–African collaborative malaria research.

French Ministry of Cooperation

Estimated US$3.4 million per annum on malaria research in Africa

Expenditure by the Ministry of Cooperation on malaria research in Africa is via three main channels:

- financial support to institutions and malaria research programmes in Senegal, Madagascar, Cameroon, Congo, Burkina-Faso and Gabon;
- support of French scientists working on French Cooperation assignments in the health research sector in Africa;
- re-entry grants (three-year awards) to African researchers trained in France to enable them to establish a research career in their home country.

Table 2.4 French Ministry of Cooperation: Training on African malaria projects in 1996–98.

Level	Number of awards	Remit of scheme
Postdoctoral	4	Two-year award held in the home country or in France
Master's	3	One-year award held in the home country or in France
Training course	50	Technical skills training held locally or regionally (duration two weeks to three months)
Total	**57**	

Training of developing-country scientists is conducted as part of the Ministry's research programmes. Table 2.4 shows training supported via malaria research programmes in 1996–98.

French Institute of Health and Medical Research
Institut National de la Santé et de la Recherche Médicale (INSERM)

US$7 million in support of developing-country scientists and collaborative awards in FYs 1995–98

INSERM is a public scientific and technological organization overseen by the French Ministries of Health and Research, whose vocation is to promote health for all. INSERM's annual budget is approximately US$488 million. INSERM supports training of developing-country scientists through several schemes:

- Poste Vert awards support non-French postdoctoral researchers at INSERM units in France. During 1995–98, 50 awards totalling US$3.9 million were made to scientists from developing countries (Africa 14, Asia 24, South America 12).
- Cooperative Agreements support collaborations between INSERM units in France and research laboratories in developing countries by providing funds for travel and research attachments in the partner laboratory. Expenditure on Cooperative Agreements in FYs 1995–98 was US$2.1 million.
- North–South networks are partnership-based awards that promote collaborations between French and foreign laboratories (at least two on each side). In 1995–97, 13 awards totalling US$1 million supported collaborations with developing countries. The scheme was discontinued in 1998.
- Workshops organized by INSERM scientists are held in developing countries. Expenditure on workshops in 1995–98 was US$80 000.

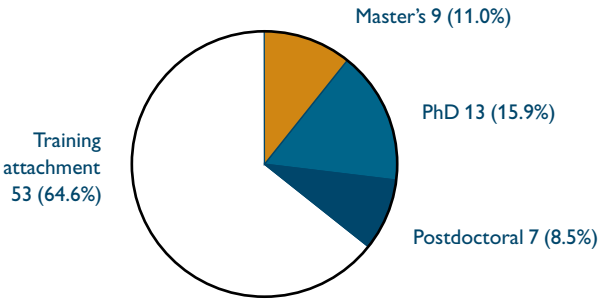
Institut de Recherche pour le Développement (IRD) (formerly ORSTOM)[2]

IRD is a state-owned public service agency under the joint authority of the French research and overseas development ministries. It offers a range of consultancy services and is involved in international research programmes through its collaborations with scientific institutes in France, Europe and developing countries. A major objective of IRD is to strengthen the scientific capabilities of developing countries through research training and specific assistance. IRD trains junior scientists through multidisciplinary research programmes in the field, in the Institute's own laboratories, or in the laboratories of its research partners. IRD also provides support for scientific networks and communities in developing countries.

IRD scientists work in research institutions in more than 15 countries in Africa. Malaria research and training programmes are based in Senegal, Ivory Coast, Cameroon and Madagascar. Data on training were obtained from the Malaria and Medical Zoology Laboratories in IRD-Dakar, Senegal. During 1995–98, 84 scientists (technicians, nurses, field doctors as well as laboratory-based researchers) received training as part of ongoing malaria research projects (Figure 2.7). IRD has similar training schemes in other countries where it supports research programmes, but figures were not available for these other programmes.

[2] In November 1998, ORSTOM became l'Institut de Recherche pour le Développement (IRD).

Figure 2.7 Malaria Research Laboratories, IRD-Dakar, Senegal: Classification of support in 1995–98 by training level.
82 African researchers received training



French non-governmental organizations

Institut Pasteur

Institut Pasteur is a private, non-profit research organization founded in 1887. It is not a funding agency *per se* and has no specific schemes of support for developing-country scientists. However, it has a history of malaria research due in part to its network of daughter institutions in malaria-endemic regions, and it supports training through its research programmes. Currently, Institut Pasteur has an integrated research programme on malaria, with emphasis on vaccine development, at four main centres:

- Institut Pasteur, Paris, France, has malaria research programmes focused on parasite biology, vaccine development and entomology. The institute conducts postgraduate training courses in infectious diseases and students working in other institutes of the network receive training in Paris towards the Diplôme d'Études Approfondies (DEA) and PhD.
- Institut Pasteur, Dakar, Senegal, has malaria research programmes in epidemiology, immunology and human genetics. The institute has research and training links with the University of Cheikh Anta Diop, Dakar, and acts as a consultant for the national malaria control programme.
- Institut Pasteur, Antananarivo, Madagascar, is an integral part of the Ministry of Health of the Malagasy Republic and contributes to national control programmes. It has collaborative and training links with the University of Antananarivo.
- Institut Pasteur, Cayenne, French Guyana, conducts research on the *Saimiri sciureus* monkey malaria model and provides a drug sensitivity screening service.

Institut Pasteur provides a small number of training grants to developing-country scientists leading to tenure in one of the institutes of its network. Approximately ten training grants have been awarded for malaria research in Senegal and Madagascar during 1995–97.

German Government

German Agency for Technical Cooperation Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ)

Technical and financial development cooperation in Germany is the responsibility of the Ministry of Economic Cooperation and Development (BMZ). The implementation of research and health projects is subcontracted to GTZ. This agency has been coordinating malaria projects since 1992 in Mali, Mauritania, Uganda and Vietnam. Training has been supported as part of these projects, although there are no dedicated award schemes for scientists. No figures were available on the number of individuals trained or the expenditure on training.

German Academic Exchange Service Deutscher Akademischer Austauschdienst (DAAD)

DAAD promotes international academic exchanges; acts as an intermediary for the implementation of foreign, cultural and academic

policy; and is involved in educational cooperation with developing countries. Funding for individuals from developing countries is provided by the Ministry of Economic Cooperation and Development (BMZ), but programmes are administered by DAAD. Programmes range from short-term exchanges to full doctoral scholarships. Several Master's courses have been designed specifically for participants from developing countries. The Master's course in Community Health and Health Management in Developing Countries at the University of Heidelberg is a WHO collaborating centre for health systems research in developing countries. DAAD awards approximately ten scholarships per annum to developing-country scientists worldwide.

German non-governmental organizations

Alexander von Humboldt Foundation

US$0.9 million in FYs 1995–98

The Alexander von Humboldt foundation is a non-profit organization which is largely supported by the German Government through its Foreign Ministry. It supports highly qualified non-German postdoctoral scholars to carry out research projects in Germany. Research may be undertaken in any subject field. In 1995–98, 22 scientists from developing countries received funding for research in biomedicine and health through the Humboldt Research Fellowship and George Forster Fellowship schemes (Africa 5, Asia 10, South America 7). Expenditure on fellowship awards was US$0.9 million.

The Netherlands Government

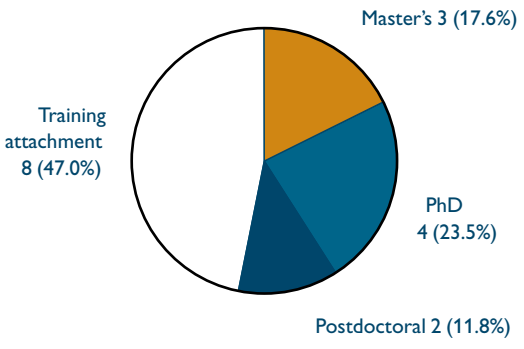
Ministry of Foreign Affairs

International development programmes in The Netherlands are administered by the Directorate General for Development Cooperation, part of the Ministry of Foreign Affairs. In the majority of programmes there is cooperation between a Dutch institution (usually a university faculty or department) and an institution in the partner country. In 1995–98, 17 scientists from developing countries were trained at the Department of Medical Microbiology, University of Nijmegen (Figure 2.8).

Norwegian Government

The Norwegian government supports training of developing-country scientists through contributions to multilateral development schemes (including the TDR programme, to which Norway is a major contributor), and bilateral development schemes. The Ministry of Foreign Affairs' bilateral department is responsible for support to the Norwegian Agency for Development and other Norwegian institutions that carry out cooperation and development research.

Figure 2.8 University of Nijmegen, The Netherlands: Classification of support by training level and region in 1995–98.
Number of individuals trained = 17



Number of individuals supported		
Africa	16	(94%)
South America	1	(6%)

The Norwegian Agency for Development Cooperation (NORAD)

The NORAD Fellowship programme provides scholarships for International Diploma and Master's courses in Norway that are designed for participants from developing countries. The programme aims to support capacity building within key institutions in prioritized countries for Norwegian development cooperation. Scholarships in the field of biomedicine and health are available for the Master's in Health Sciences (International Health) course at the University of Bergen and the Master's in International Community Health course at the University of Oslo.

Portuguese Government

Training of developing-country scientists is supported by various government agencies and non-governmental organizations in Portugal. The Ministries of Science and Technology, Foreign Affairs, and Health fund training through bilateral agreements or individual research projects.

Institute of Hygiene and Tropical Medicine, New University of Lisbon, Portugal

The Institute of Hygiene and Tropical Medicine (IHTM) in Lisbon conducts postgraduate courses of relevance to developing-country scientists and has research links with several African countries. The Centre for Studies on Malaria and other Tropical Diseases, which is based within the IHTM and funded directly from the Ministry of Science and Technology, is also involved in training, predominantly through its research collaborations with African countries. The data presented in this report reflect training carried out by the IHTM and the Centre for Malaria Studies, excluding clinical training activities. In 1995–98, 82 scientists received training, mainly via attachments and diploma courses (Figure 2.9).

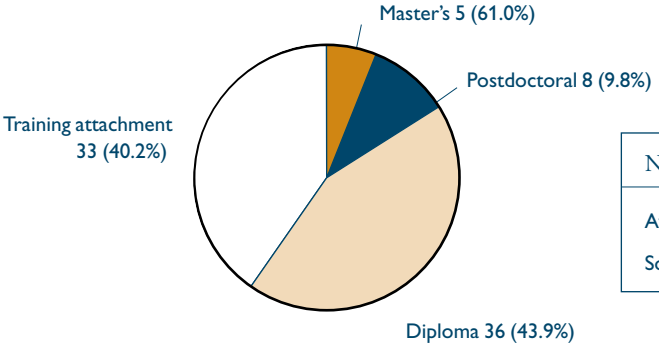
Swedish Government

The Swedish International Development Cooperation Agency (Sida)

Sida administers Swedish aid programmes. Within Sida, the Department of Research Cooperation, SAREC, supports research and strengthening of research capacity in developing countries. The data presented in this report refer to years 1996 and 1997. SAREC supports biomedical/health research via three main channels:

- Country-based and Regional Research Cooperation. SAREC expenditure for 1996 and 1997 was US$10.2 million. Examples in the field of parasitic research include a Tanzania–Sweden collaborative project on management of childhood malaria in primary healthcare institutions and a study of the impact of land use change on socio-economic status and incidence of malaria and schistosomiasis in Ethiopia.

Figure 2.9 Institute of Hygiene and Tropical Medicine, Portugal: Classification of support by training level and region in 1995–98.
Number of individuals trained = 82



Number of individuals supported		
Africa	78	(95%)
South America	4	(5%)

- International research programmes and other special programmes and projects, including the TDR programme to which Sida/SAREC is a major contributor (Annex 1). SAREC expenditure in 1996 and 1997 was US$9.3 million.
- Research grants to Swedish institutions on application. Expenditure in 1996 and 1997 was US$2.5 million. The research projects must be of relevance to developing countries and are often carried out in collaboration with institutions in developing countries.

SAREC has no fixed budget for training: expenditure varies on a project or needs basis, although, in general, a high proportion of the programme budget is devoted to training. Training may be conducted locally, or via the 'sandwich' model where students combine work in their own university departments with studies at a Swedish institution.

Swiss Government

The Swiss Government supports training and research cooperation with developing countries through a variety of channels. The figures presented in this report are underestimates of the total expenditure, due to difficulties in tracing contributions from the various sources.

Swiss Agency for Development and Cooperation (SDC)

The SDC is responsible for bilateral development cooperation, which is concentrated on 16 target countries in Africa, Asia and South America. SDC supports training in a range of subjects, with emphasis on management of public affairs, the environment, agriculture and health. The majority of health research training is conducted at two Swiss institutions: the WHO Immunology Research and Training Centre (IRTC), Lausanne, and the Swiss Tropical Institute (STI), Basle.

The IRTC runs a seven-week Immunology, Vaccinology and Biotechnology Applied to Infectious Diseases course (in English and French) for health professionals from developing countries. Refresher courses are held in developing countries for previous course attendees. SDC provides an annual award of US$0.4 million to WHO to cover training costs.

The STI offers a range of courses of interest to health professionals working in developing countries, and it is a partner in development projects that are largely financed by SDC. For example, more than half of the participants on the Health Care and Management in Tropical Countries (HCMTC) are from developing countries. A high proportion receives scholarship support from SDC.

SDC expenditure in FYs 1995–97 on scholarships in health was US$3 million. A total of 135 scholarships was awarded, mainly for courses and training attachments (Africa 81, Asia 37, South America 17). It should be noted that these figures do not include training conducted as part of research programmes and development projects, for example on STI collaborative projects with developing countries.

Swiss National Science Foundation (SNSF)

The SNSF was established in 1952 to promote basic scientific research at Swiss universities and other scientific institutions. Research grants constitute about 75 per cent of the budget of the SNSF, and are distributed in all areas of science (Humanities and Social Sciences, Mathematics, Natural and Engineering Sciences, Biology and Medicine). Fellowships and research grants are awarded mainly to Swiss researchers, but SNSF also supports efforts to encourage collaborations between Swiss scientists and researchers in developing countries. The SNSF, in conjunction with the SDC, supports specific projects on Environment and Development, which are conducted by researchers in developing countries working in collaboration with Swiss research groups.

Federal Commission for Scholarships for foreign students (FCS), Switzerland

The Swiss Government offers scholarships via the FCS to foreign postgraduate students who wish to study or undertake research work in any subject field at Swiss universities. The scholarships are offered to governments of developing countries on a unilateral basis. During 1995–98, 55 students from developing countries received

scholarship support for studies in biomedicine and health. In the last few years, an annual scholarship support of approximately US$2.2 million has been awarded to students from developing countries.

UK Government

UK Department for International Development (DFID)

DFID is the government department responsible for promoting development and the reduction of poverty. It manages Britain's bilateral and multilateral development programmes. DFID has no specific award schemes for developing-country scientists, but provides training as part of its bilateral programmes. It also allocates funds to support training administered by the UK Medical Research Council and the British Council, and it is a major donor to the TDR programme (Annex 1). DFID does not hold central records on training conducted through its development projects, therefore the African regional offices were contacted for further information. A total of 30 students received training as part of DFID projects in Uganda, Zambia and Kenya during 1994–98 (Master's 18, training attachments 12). Training is not normally provided beyond Master's level.

The British Council

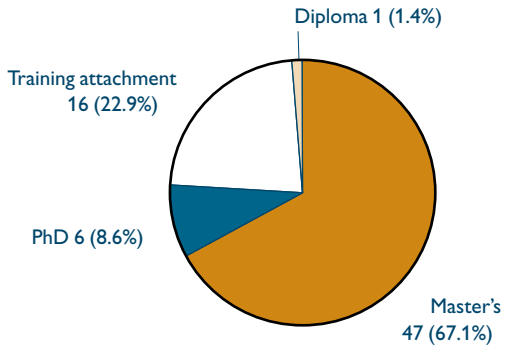
The British Council promotes educational, cultural and technical cooperation between Britain and other countries. The Council's work is designed to establish long-term and worldwide partnerships, and to improve international understanding. Schemes managed by the British Council in 1995–98 supported 70 students from developing countries in studies in biomedicine and health. The majority of awards were at Master's level (Figure 2.10). Training was conducted in the UK.

UK Medical Research Council (MRC)

The MRC is a UK governmental research organization. Its mission is to improve health by promoting research into all areas of medical and related science. It supports medical research in three main ways: through its research establishments; grants to individual scientists; and support for postgraduate students. The MRC total annual budget in FY 1997 was US$485 million.

The MRC supports major research programmes in Africa (The Gambia and Uganda) and Jamaica. Training of local researchers in The Gambia occurs through several mechanisms. The MRC Laboratories in The Gambia are recognized by the UK Open University as a sponsoring establishment for research degrees, and sever-

Figure 2.10 The British Council: Classification of support by training level and region in FYs 1995–98.
Number of individuals trained = 70



Number of individuals supported		
Africa	21	(30%)
Asia	28	(40%)
South America	21	(30%)

al students have undertaken studies through the Open University. Study at local or overseas universities is also supported. In Uganda, the MRC receives an annual allocation from DFID for vocational and technical training of Ugandan staff. In Jamaica, the MRC Laboratories will shortly be transferred to the University of the West Indies. Collaborations and interchanges of scientists between UK and Jamaica are encouraged. Under the recently re-launched Rogers Fund, local researchers and technicians in The Gambia, Uganda and Jamaica may undertake a structured training programme usually lasting one year in an MRC research establishment.

UK non-governmental organizations

The Wellcome Trust

US$17.7 million in FYs 1995–98

The Wellcome Trust is an independent, private charity that funds research in the biomedical sciences and the history of medicine. Established in 1936 under the will of Sir Henry Wellcome, a successful industrialist and philanthropist, the Trust is currently the world's largest medical research charity. Total expenditure on research awards in FY 1998 was US$345 million. Although the greater part of the Trust's income supports the work of researchers in UK and the Republic of Ireland, its international activities are currently being expanded. The Trust has a history of providing support for tropical medicine research. Major research programmes outside the UK are currently funded in Kenya, Malawi, Thailand, Vietnam and South Africa.

A range of award schemes is open to scientists internationally; several have a focus on developing countries. In FYs 1995–98, the Trust's expenditure on awards to developing-country scientists increased 16-fold and totalled US$17.7 million (Figure 2.11). These figures are generally restricted to individual training and career development awards, and exclude expenditure on major programmes of research in developing countries. The majority of the Trust's programmes are aimed at postdoctoral scientists and medical or veterinary researchers (Figure 2.12), with fewer awards at earlier career stages. Awards are normally available for all research relevant to health or disease in developing countries. In addition, a number of specific schemes are offered to encourage research on noncommunicable diseases, population studies and reproductive health, health services research and clinical epidemiology. Postdoctoral awards relevant to this survey are:

- Travelling fellowships: awards to individual scientists to travel to another country (usually the UK) to carry out a research project. Awards include project costs, travel and a stipend for the period spent overseas.
- Training fellowships: up to four years' support for a study focusing on a health problem of relevance to the trainee's home country. Training (including Master's training where appropriate) may be in centres of excellence in the developing world or the UK, but a substantial part of the trainee's time should be spent in the home institute.
- Collaborative awards: support for a research project in a developing country led by one principal investigator, with scientific support from a developed country. Awards are available to postdoctoral researchers returning home after a period of training in the UK as well as for more senior researchers. Collaborations may link the UK and any developing country; South Africa and sub-Saharan Africa; or Australia/New Zealand and South-East Asia.
- Project and programme grants: three- to five-year awards to scientists in their home country that provide the full direct costs of research projects focusing on health problems of local significance.

Training at Master's and PhD level is provided mainly in association with large overseas research programmes such as those in Kenya, Thailand and Malawi, rather than through dedicated award schemes. However, a Research Training Fellowship at Master's Level in Population Studies has been introduced recently.

Figure 2.11 Wellcome Trust: Expenditure on training of developing-country scientists.
Total expenditure in FYs 1995–98 was US$17.7 million

Figures exclude expenditure on major research programmes led by UK investigators. However, the 1998 figure includes one large award to a developing-country institute (US$2.2 million)

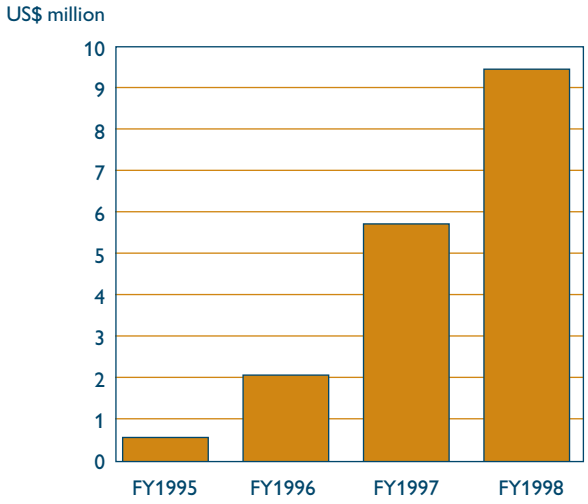
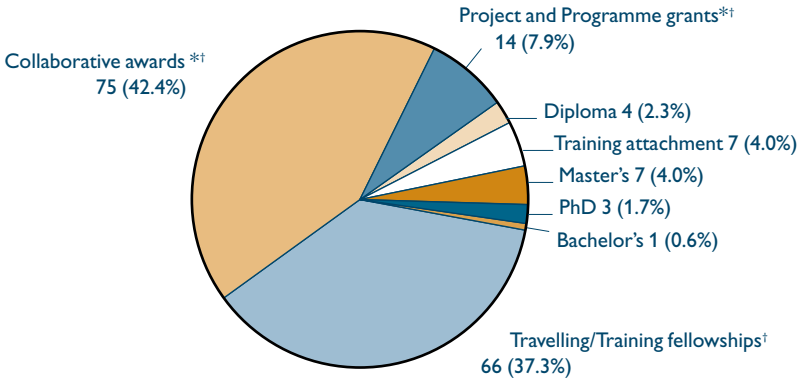


Figure 2.12 Wellcome Trust: Classification of support by training level and region in FYs 1995–98.
Expenditure on training was US$17.7 million
Number of individuals supported = 177



Number of individuals supported		
Africa	76	(43%)
Asia	65	(37%)
South America	36	(20%)

*Excludes major project and programme grants to UK investigators based in developng countries that may include support for training of local scientists
†Postdoctoral awards

2.2.3 Asia and Australia

Japanese Government

Japan International Cooperation Agency (JICA)

Estimated US$89 million on health training in FYs 1995–97

Japan's Development Assistance programme comprises three main categories: bilateral grants, bilateral loans, and contributions to multilateral donor organizations. JICA administers approximately 60 per cent of the bilateral grants. Training programmes delivered through bilateral grants are of three types:

- training programmes conducted in Japan;
- training programmes in a developing country for local participants;
- training programmes in a developing country for local and regional participants.

The data presented in this report are limited to training programmes conducted in Japan. (Expenditure on training in health was estimated from the mean expenditure per person on training in all sectors.) All training was in the form of short courses on a wide range of subjects in health and medicine, including infectious diseases, public health, oncology and occupational health. More than half of the trainees were from Asia (Table 2.5).

Table 2.5 JICA: Participants on Health training courses in Japan FYs 1995–97.

Africa	787	(22%)
Asia	1871	(51%)
South America	972	(27%)

Australian Government

Australian Agency for International Development (AusAID)

AusAID manages Australia's development cooperation programmes. Education and training constitutes around 20 per cent of the total development cooperation budget. Support is provided for technical and further education training, undergraduate and postgraduate studies, and training can take place in Australia, in the home country, or in another developing country. Currently, the majority of training is conducted in Australia through the Australian Development Scholarships scheme. A recent review of training awards showed that as at March 1998 there were 3851 AusAID-funded students, mainly from Asia and the Pacific Islands, engaged in higher education and technical and further education.[3] Of these, 10 per cent were engaged in Health and Community Services training. The overall breakdown of awards in all subject areas was approximately 1400 awards at Bachelor's level, 1400 at Master's, and 600 at PhD level.

2.2.4 International organizations

The UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR)

Estimated US$22 million on Research Capability Strengthening Grants 1995–98

The Special Programme for Research and Training in Tropical Diseases (TDR) is co-sponsored by the United Nations Development Programme (UNDP), the World Bank and the World Health Organization (WHO). TDR is supported by voluntary contributions from governments, international organizations, charities and other non-governmental bodies (see Annex 1 for contributions to the programme in 1989–98).

The programme has two objectives: to research and develop new tools to control TDR target tropical diseases (malaria, schistosomiasis, leishmaniasis, lymphatic filariasis, onchocerciasis, African trypanosomiasis, Chagas disease and leprosy) and to increase the research capability in developing countries through training of individuals and strengthening of institutions. The total annual TDR grants budget [Research Capability Strengthening (RCS) and Research and Development] is US$18.5 million, of which US$5.5 million is devoted to RCS for institutional and training support).

Within RCS, training support to developing-country scientists is via Research Training Grants (RTG) and Re-entry Grants. RTGs are awarded on a competitive basis for studies at Master's, PhD or postdoctoral level, or for acquiring specialized skills. Studies are restricted to one or more of the TDR target diseases in any of

[3] Australian Agency for International Development 'Snapshot of Training' as of 31 March 1998.

the laboratory, clinical or applied field research disciplines. Preference is given to applicants from countries with lesser developed research capacities, and to those who wish to pursue studies in their own country or within their own region. TDR expenditure on RTGs in 1995–98 was US$8.3 million. In the same period, TDR Research Training Grants supported 193 researchers, predominantly at Master's and PhD level. The majority of awards were directed to scientists in Africa (Figure 2.13).

Re-entry Grants provide support for researchers, who have recently completed post-graduate training, to establish an independent research programme or laboratory in the home country. In 1995–98, 43 Re-entry Grants were awarded. TDR expenditure on Re-entry Grants averages US$0.5 million per year.

The TDR Multilateral Initiative on Malaria Task Force is a time-limited programme to support malaria research capability strengthening in Africa. Awards support collaborative projects between partners in developed and developing countries. Projects must include at least two African research institutions (one established and one emerging) and at least one international partner. Training is an integral element of the programme. Fifteen awards were made in February 1998 at a cost of US$2.5 million.

Within TDR's other grant formats, training opportunities are available and encouraged. In addition to training administered through dedicated award schemes, TDR conducts short-term training courses in specialist areas.

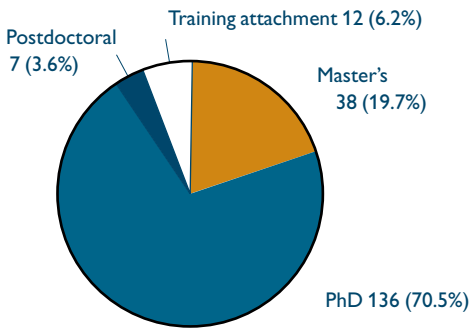
The International Atomic Energy Agency (IAEA)

The IAEA serves as the world's central intergovernmental forum for scientific and technical cooperation in the nuclear field. The Agency seeks to enhance the capabilities of developing Member States to address important health problems through the development and application of nuclear and related techniques. Human health activities focus on methods for curative and palliative treatment of cancer and the establishment of comprehensive quality assurance programmes for radiation dosimetry, on techniques for early diagnosis of diseases such as tuberculosis, and effective nutritional studies. Assistance to developing countries is made via two principal mechanisms: Technical Cooperation Projects (TCP) and Co-ordinated Research Projects (CRP).

TCP awards have a problem-solving orientation. They seek to contribute, in a cost-effective manner through the provision of experts, training and equipment, to activities addressing high development priorities relating to health services in Member States.

CRP awards provide support for three years for networks of research institutions working together on a specific topic. The aim of the CRP is to promote high-quality research in developing and developed countries (the latter provide cost-free expertise to the projects). The Agency's expenditure during 1997–98 on malaria research and associated training was US$1.0 million. In addition, the Agency convenes and sponsors seminars, symposia and international conferences, and disseminates information through cost-free publications.

Figure 2.13 TDR: Classification of support by training level and region in FYs 1995–98. These figures are restricted to training via the Research Training Grant Scheme.
Number of individuals trained = 193



Number of individuals supported		
Africa	120	(62%)
Asia	38	(20%)
South America	35	(18%)

2.2.5 Developing Countries

Brazilian Government

Ministry of Science and Technology
Ministerio da Ciencia e Tecnologia (MCT)
US$71.5 million on research and training through FINEP, CNPq and INPA in FYs 1995–97

MCT is responsible for the planning, coordination, supervision and control of all activities relating to science and technology in Brazil. Within MCT, there are three collegiate bodies, four secretariats, two funding agencies and four research institutes (for further information see Brazil: a science and technology profile, Bogliolo, 1998). The two funding agencies are the National Council for the Development of Science and Technology (Conselho Nacional de Desenvolvimento Científico e Tecnológico, CNPq) and the Brazilian Agency for the Funding of Studies and Projects (Financiadora de Estudos e Projectos, FINEP).

CNPq is mainly concerned with the training and qualification of human resources, and with support for research. Its funding activities are divided into Basic Programmes for traditional fields of knowledge and Special Programmes for strategic areas and multidisciplinary projects. CNPq expenditure on scholarships and research grants in biomedicine and health in FYs 1995–97 was US$65.6 million (Figure 2.14).

FINEP is a state-owned company attached to MCT, with responsibility for financing Brazil's technological development. FINEP provides support in the form of loans for public and private enterprises, and universities and research centres. FINEP expenditure on research projects in biomedicine in FYs 1995–98 was US$4.2 million. An additional US$72 000 provided support for scientific meetings and publications on health sciences.

The National Amazon Research Institute
Instituto Nacional de Pesquisas da Amazonia (INPA)

INPA is one of the four research institutes attached to MCT. It was established in 1952 to undertake scientific research of the physical environment and living conditions in the Amazon region. It also trains personnel to carry out research in the region by means of Master's and doctoral courses. Biomedical research and training at INPA is focused on studies of the vectors of malaria and leishmaniasis. Expenditure on 40 training awards made during FYs 1995–98 was US$1.7 million (Figure 2.15).

Fig. 2.14 CNPq: Classification of awards in FYs 1995–97.
Expenditure was US$65.6 million
Number of individuals trained = 6072

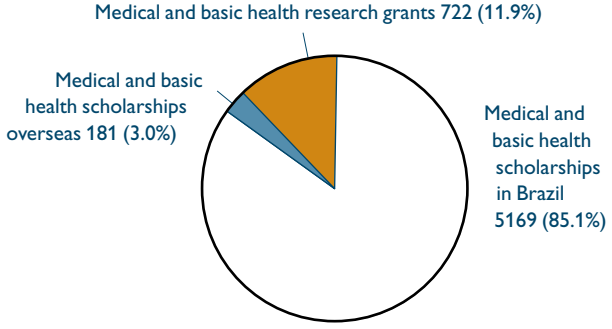


Fig. 2.15 INPA: Classification of awards by training level FYs 1995–98.
Expenditure on training was US$1.7 million
Number of individuals trained = 39

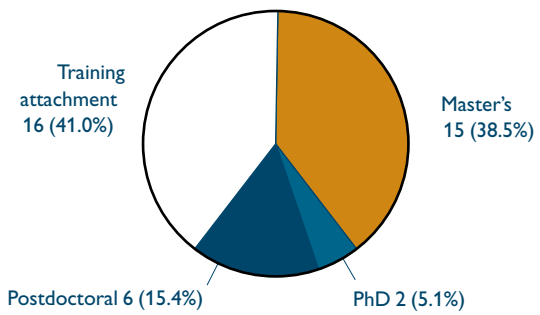
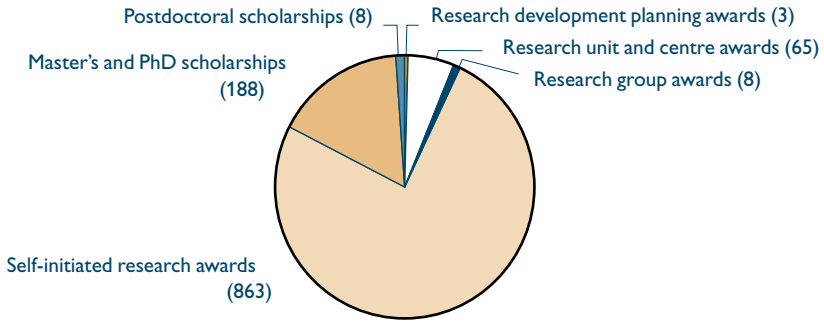


Figure 2.16 South African MRC: Classification of awards in FYs 1995–98.
Expenditure was US$10.7 million



All awards were made to South African citizens or permanent residents.

South African Government

South African Medical Research Council

US$10.7 million on health research in FYs 1995–98

The South African Medical Research Council is the main government funding agency for health research in South Africa. It has several award schemes open to South African researchers:

- research unit and centre awards support the creation of a research unit around an internationally recognized leader;
- research group awards enable establishment of a group in a strategic area to develop health research capacity;
- research development planning grants provide support to historically disadvantaged institutions in South Africa;
- self-initiated research awards provide research grants to independent researchers;
- fellowships and postgraduate scholarships.

MRC expenditure on awards was US$10.7 million in FYs 1995–98. Figure 2.16 shows the breakdown of awards.

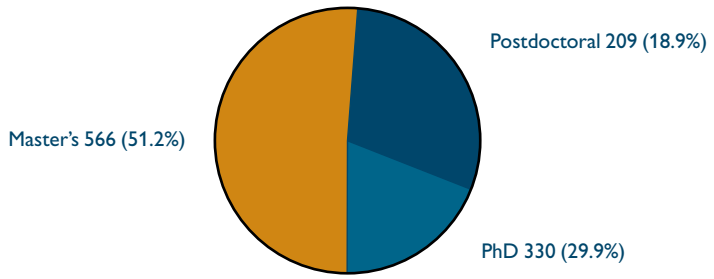
National Research Foundation (NRF)

US$3.2 million on training in FYs 1997–98

The NRF is a newly created institution in South Africa that combines the functions of the former Foundation for Research Development and the Centre for Science Development. The objective of the NRF is to support and promote research through funding, human resource development, innovation and development in all fields of science and technology. In so doing, it contributes to the improvement of the quality of life of all the people of the country. The NRF has several mechanisms of support in the fields of the natural and applied sciences, engineering and technology within its various programmes, including:

- free-standing bursaries, scholarships and fellowships (awarded to students directly in this programme, based on merit and potential);
- grant holder bursaries (awarded by principal grant-holders funded in the Open Research Programme and programmes in the directed themes);
- institutional student support awarded through programmes to develop institutional research culture at historically disadvantaged universities and technikons.

Figure 2.17 South African NRF: Classification of awards in FYs 1997–98.
Expenditure was US$3.2 million. Number of individuals trained = 1105



Expenditure on Master's, PhD and postdoctoral awards in health and biomedical sciences in 1997 and 1998 totalled US$3.32 million. Figure 2.17 shows the breakdown of these awards.

A limited number of awards is offered to South African researchers in health sciences through the Open Research Programme. In FY 1998, 38 awards totalling US$0.5 million were made to scientists in the field of biochemistry. Four awards (US$40 000) were for malaria research.

South-East Asia

SouthEast Asian Ministers of Education Organization Regional Tropical Medicine and Public Health Network (SEAMEO-TROPMED)

US$2.3 million on training and special projects FYs 1995–97

SEAMEO-TROPMED's mission is to develop the capacity of individuals and institutions to deliver quality healthcare through training and research. The network offers academic degree programmes and a range of short-term courses and workshops, including distance learning modules. Its four regional health centres conduct research and offer training in the following fields of speciality:

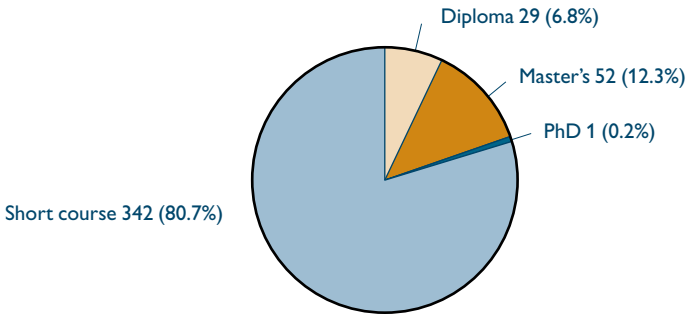
- TROPMED/Indonesia at the University of Indonesia, Jakarta is the Regional Centre for Community Nutrition;
- TROPMED/Malaysia at the Institute of Medical Research, Kuala Lumpur is the Regional Centre for Microbiology, Parasitology and Entomology;
- TROPMED/The Philippines at the University of The Philippines, Manila is the Regional Centre for Public Health;
- TROPMED/Thailand at Mahidol University, Bangkok, is the Regional Centre for Tropical Medicine.

Expenditure on training courses, scholarships and special projects was US$2.3 million in FYs 1995–97. A proportion of SEAMEO's funding is provided by partner organizations with whom SEAMEO organizes special projects and courses. These include the GTZ-supported HIV/AIDS/STD Partnership project in the Asia region, and the SEAMEO–France Cooperation Programme on Control of Communicable Diseases. During FY 1997, 424 students, mainly from Asia, received scholarship support from SEAMEO (Figure 2.18).

2.3 OVERVIEW OF AWARDS AND DISCUSSION

The present survey gathered comparative data from a range of funding organizations on research training opportunities in health and the biomedical sciences in developing countries. Previous reviews of have tended to be qualitative in nature or limited in their scope, whereas the present study provides a much broader analytical overview of the availability of training opportunities at the various stages of career progression, in different disciplines and in different regions. This study, however, has not attempted to assess the success of training schemes, either individually or collectively, in building sustainable and productive research capacity in developing countries. Data are therefore limited to numbers of trainees, expenditure figures and descriptive information on training mechanisms. Some

Figure 2.18 SEAMEO scholarship recipients in FY 1997.
The figures exclude course participants who received support from other sources
Number of individuals trained = 424



indicators of the current levels of research activity in developing countries and of the effectiveness of training schemes are presented in later chapters. However, more detailed assessments by individual organizations are needed to yield answers on optimal training mechanisms.

Collecting comparable and reliable data on international support for training developing-country scientists represented a significant challenge. The quality and quantity of data collected from individual organizations varied, and inevitably there were omissions in the overall international data obtained. A particular difficulty was in obtaining details of training that was delivered as part of a larger research or development programme, as this training was often not recorded separately or monitored. Nevertheless, a substantial body of data was collected and an overview is presented here. This resource of information should be of value both to funding agencies considering their contributions to training, and to researchers seeking financial support. Contact details for funders surveyed are provided in Annex 2.

2.3.1 Investors in training

The 39 organizations that participated in the survey included governmental and non-governmental organizations, private foundations and international organizations. Information from governmental agencies in two lower-income countries (Brazil and South Africa) was also obtained.

Resources from governments in developed regions principally flow to low- or middle-income countries through specialized research councils or agencies, bilateral programmes of foreign assistance agencies or ministries, or contributions to multilateral institutes or organizations such as the UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR). Most private foundations and non-governmental organizations administer their own funding schemes, but some also contribute to other agencies. Where possible, this report has given due credit to organizations providing funds to secondary agencies, but the principal focus is on the point of administration of training schemes. Training provided through bilateral resources was often difficult to identify through survey of funding organizations, due to decentralization of records. Further information on organizations for which data were incomplete was in some cases obtained by direct survey of malaria research laboratories (see Chapter 4).

The results of the survey clearly showed the immense number and variety of schemes offered by the international funding community, each individual scheme having its own aim and remit. The majority of funding organizations provide relatively small numbers of training awards each year, and only a few funders operate larger-scale training schemes: namely the Japanese Inter-national Cooperation Agency (JICA), the European Commission INCO-DC programme in DG XII, the US National Institutes of Health and WHO/TDR. Other more prominent direct supporters of training include Australian, French, Swedish, Swiss, Danish and Belgian Government agencies, the International Clinical Epidemiology Network (INCLEN) and the Wellcome Trust.

2.3.2 Expenditure

Table 2.6 summarizes the expenditure on training identified in this survey. Although every effort was made to present only the direct expenditure on training, this was not always possible, and the footnotes to the table provide additional information.

Aggregate identified expenditure on training of developing-country scientists in biomedicine and health by organizations in higher-income countries was US$261 million (FYs 1995–97), with nearly a third of this from JICA. This figure represents a minimum estimate of expenditure due to the incompleteness of information received from a number of organizations, and difficulties in achieving comprehensive survey coverage of all relevant funders. For example, the survey focused on TDR as the largest WHO programme providing research training for scientists in developing countries, and does not include other WHO programmes such as that for Training in Human Reproduction (HRP); nor other multilateral institutes or agencies such as PAHO and UNICEF. In addition, responses were not obtained from a number of private foundations. Nevertheless, the survey almost certainly captured the majority of larger contributors from the established market economies (for an overview of investors in health research in general, see Michaud and Murray, 1996).

The trend in investment in research training in developing countries was upwards, with an increase of 41 per cent during the three-year period 1995–97 (data not adjusted for inflation; Figure 2.19). Several organizations reported further increases in 1998. Those organizations showing the most notable increases in training expenditure were the US National Institutes of

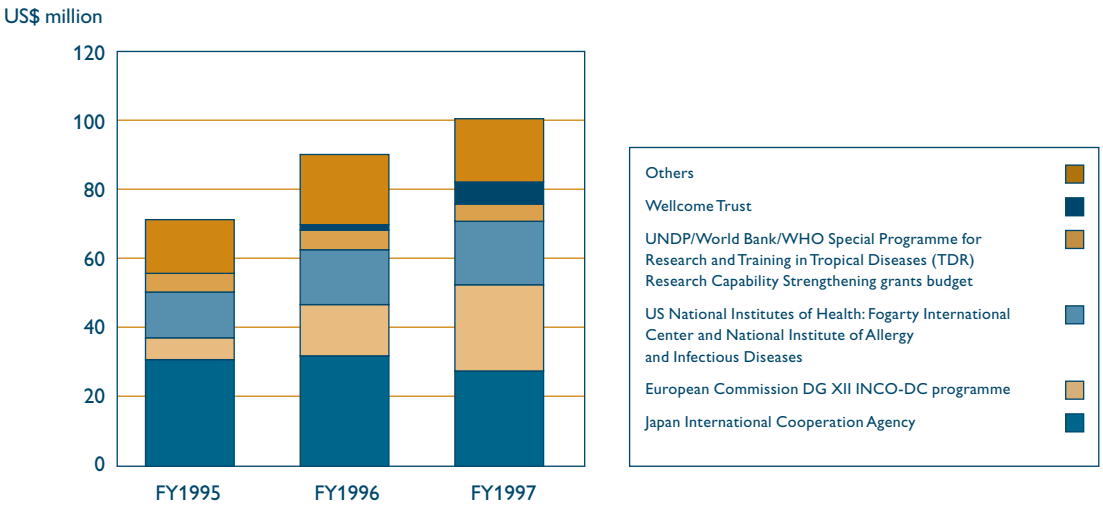
Table 2.6 Summary of identified support for training developing-country scientists in FYs 1995–97.

Funder	Expenditure in FYs 1995–97 (US$million)
Japan International Cooperation Agency (JICA) [1]	89.4
Brazilian Government and associated agencies [2]	71.5
European Commission DG XII [3]	46.9
US National Institutes of Health: Fogarty International Center and National Institute of Allergy and Infectious Diseases	46.7
UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR) [4]	16.5
South African MRC and NRF [5]	11.9
Swedish International Development Cooperation Agency (Sida) [6]	10.2
French Ministry of Cooperation [7]	10.2
Wellcome Trust	8.2
Federal Commission for Scholarships for foreign students Switzerland	6.6
Belgian Administration for Development Cooperation [8]	6.6
Institut National de la Santé et de la Recherche Médicale (INSERM) [9]	6.3
Danish Bilharziasis Laboratory	4.5
International Clinical Epidemiology Network (INCLEN)	4.4
Swiss Agency for Development and Cooperation [10]	3.0
SEAMEO-TROPMED [11]	2.3
Others	2.4

All available figures for expenditure on training developing-country scientists are included in the above table, but it should be noted that: (a) Some organizations are not listed as they only provided qualitative information on training; (b) Figures listed for some organizations represent only a portion of their training activities; (c) Organizations providing training funds via another agency are not listed here.

1 Estimated expenditure on training courses held in Japan, one part of Japan's training activities
2 Research programmes and scholarships
3 Expenditure on the INCO-DC Health programme (not restricted to training)
4 Research capability strengthening and institutional support
5 Health research grants from MRC. NRF figures are for 1997–98 only
6 Expenditure on country-based research cooperation and special projects for 1996 and 1997
7 Estimated expenditure on French–African collaborative malaria research
8 Scholarships and support to institutions in developing countries
9 Expenditure on collaborative schemes with developing countries and training awards
10 Expenditure on scholarships to developing-country scientists, one part of SDC training activities
11 Expenditure on scholarships, courses and special projects for 1995–97

Figure 2.19 Expenditure in FYs 1995–97 on training scientists in developing countries. Restricted to organizations in developed countries



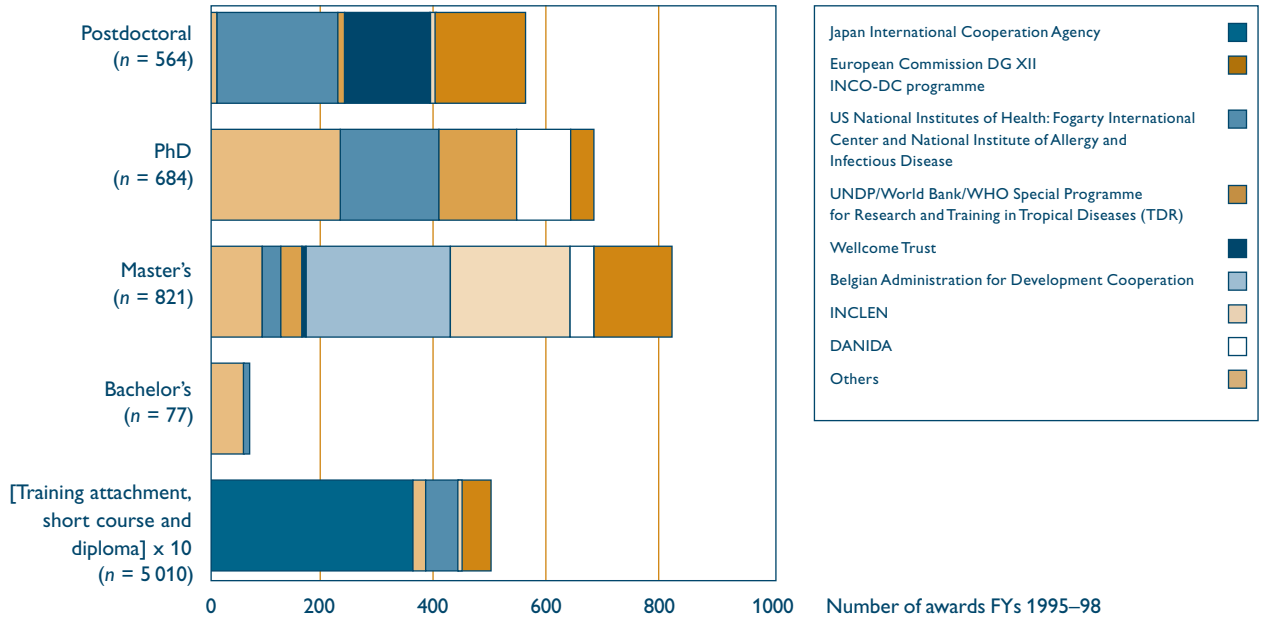
Health, the Wellcome Trust and the European Commission DG XII INCO-DC programme.

Data were available from some organizations on the significance of their investment in training of developing-country scientists in relation to overall expenditure. In 1998, the US National Institutes of Health (NIH) committed US$24 million to training scientists in developing regions (dedicated training schemes only), representing 0.15 per cent of the total NIH budget and an estimated 6 per cent of expenditure on research relevant to developing countries (Michaud and Murray, 1996). The Wellcome Trust's expenditure on training of developing-country scientists increased from 0.17 per cent of the total research funding in 1995 to 1.5 per cent in 1997. Overall, approximately 10 per cent of the Trust's total grants expenditure goes to research relevant to developing regions and, in 1997, 15 per cent of this was for training. The above figures show that training of scientists in lower-income countries represents a small proportion of overall activities for NIH and the Wellcome Trust. These two organizations are leading international funders of research into diseases that predominantly afflict developing countries, and a small increase in the proportion of their budgets allocated to training has the potential to make a large global impact. In fact, the expenditures of both the Wellcome Trust and NIH on training overseas scientists have already increased over the last few years. It should be noted that the US Government, in addition to contributing through NIH, also provides training through CDC and USAID, and via WHO/TDR.

The review focused primarily on training support from organizations based in higher-income countries and did not attempt to obtain comprehensive data from developing countries. Estimates of financial investment in research and development by governments in lower-income regions are generally very low, although there is substantial variation between countries (UNESCO, 1998). Information was obtained in the current study from the governments of two lower-income countries: Brazil made important contributions to training of local scientists and research projects (US$71.5 million in 1995–97), while South Africa made more modest contributions (about US$8.6 million in 1997–98). Brazil and South Africa have the highest levels of research and development expenditure for their respective regions and the figures from these two countries therefore probably represent the upper levels of government commitment to training. The figures from South Africa in particular suggest that investments by other countries in sub-Saharan Africa are extremely low, and these countries are therefore likely to be heavily dependent on external funding resources to maintain research activities.

Data were also requested from organizations on training of developing-country scientists in

Figure 2.20 Availability of training at different levels in FYs 1995–98.



Notes:
- Figures exclude local support within developing countries (South Africa and Brazil)
- TDR figures include Research Training Grants only (excludes Re-entry Grants and Postdoctoral project grants)
- DANIDA training was supported through the Danish Bilharziasis Laboratory
- AusAID provide large numbers of awards at Bachelor's, Master's and PhD level to scientists in Asia and the Pacific islands, but directly comparable figures were not available

malaria research. The US National Institutes of Health and the Wellcome Trust devoted approximately 2 per cent of their training expenditure to malaria in 1995–98, reflecting the broad remit of their training schemes.[4] In contrast, 20 per cent of the INCO-DC Health budget was devoted to malaria during 1995–98 and a recent review of TDR Research Training Grants revealed that 42 per cent of PhD awards in 1991–97 supported projects on malaria (TDR, 1999).

2.3.3 Training level of awards

The availability of support at different stages of career progression was assessed by analysing the number of awards and the principal contributing organizations at each training level (Figure 2.20).

Training attachments and short courses were the predominant forms of support identified in the survey, accounting for 5010 awards (70 per cent of total identified awards). Many organizations support this type of training, although JICA provided the greatest number, particularly to Asian countries. Detailed information on the nature of training attachments, such as the stage of scientific career where they were most often directed, was not available. Many organizations also provide support for training workshops and the US NIH was notable in this respect.

At undergraduate level there were very few opportunities for support from agencies internationally: only 1 per cent of all identified awards were for Bachelor's studies. Available data indicated that the European Commission INCO-DC programme and AusAID provided the highest numbers of awards at this level.

Postgraduate training identified in the study (excluding training attachments) comprised 821 Master's awards (40 per cent of total), 684 PhD awards (33 per cent) and 564 postdoctoral awards (27 per cent) for the period 1995–98. Again, these are likely to be underestimates due to the incompleteness of data. For example, the large numbers of AusAID awards to scientists in Asia and the Pacific islands were not included in overview analyses due to a lack of precise data. Similarly, data from French agencies were incomplete. Nevertheless, the aggregate figures include the majority of larger funders and provide an indication of the order of magnitude of postgraduate training opportunities.

[4] Malaria represents about a third of Wellcome Trust expenditure on tropical medicine research activities overall.

Many of the organizations that participated in the survey (74 per cent of the total) offered Master's training, although the majority provided only small numbers of awards each year. A few organizations provided substantial support at Master's level: the Belgian Agency for Development Cooperation (BADC) and the International Clinical Epidemiology Network (INCLEN) provided 256 and 209 awards in 1995–98 respectively, accounting for over half of the total Master's awards identified. Other prominent supporters of Master's training during 1995–98 were the INCO-DC programme (100 awards), the British Council and DANIDA (40–50 awards each). The awards provided by INCLEN and BADC were focused in the areas of clinical epidemiology and public health respectively, so that the availability of Master's training in other research disciplines was more limited.

Support at PhD level was available from just over half of funding organizations surveyed, but 94 per cent of the identified awards came from four organizations: the European Commission, NIH, TDR and DANIDA (through the Danish Bilharziasis Laboratory). Partial data provided by AusAID, IRD, Sida/SAREC and the Swiss Agency for Development and Cooperation suggested that these agencies may also make important contributions to training at PhD level. Contributions from some of these agencies were confirmed by direct survey of African laboratories (Chapter 4).

Identification of opportunities for postdoctoral scientists to extend their scientific skills and consolidate their PhD training was complicated by the differing definitions and perceptions of 'training' and the lack of formalized qualifications at this level. It is likely that a proportion of the identified large number of training attachments and workshops are aimed at postdoctoral scientists, although insufficient information was available to confirm this. Postdoctoral scientists can also extend their experience by working in association with ongoing research projects, and there are a number of bilateral awards to support exchange of scientists between high- and low-income countries. Accurate assessment of the extent of these types of postdoctoral training was difficult as they are often an integral part of a larger programme.

Few opportunities were identified for postdoctoral scientists to apply for research funds to develop their own individual careers; the majority of support going to larger-scale programmes. TDR, NIH, and the Wellcome Trust appear to offer the most extensive possibilities for support in this respect, although most TDR grant opportunities are focused on strategic priority areas or linked to institutional strengthening grants. TDR also provides small one- to two-year Re-entry Grants to researchers upon return to their home institution after a period of training. The Wellcome Trust offers schemes to develop the expertise of junior postdoctoral researchers, including opportunities to train in or collaborate with centres of excellence in developing countries or in the UK, as well as awards for more senior scientists. NIH offers international research fellowships to support postdoctoral training of foreign scientists in the USA and in addition, unsolicited grant applications are accepted from non-US citizens.

2.3.4 Geographical distribution of awards

Geographical information was available for just over half of the agencies contacted and 89 per cent of the specific awards identified in the survey (local support from Brazil and South Africa was excluded from the analysis). Overall, the regional distribution of awards in FY 1995–98 was Asia 41 per cent, Africa 32 per cent and South America 27 per cent, but the distribution was strongly skewed by the very large number of awards to Asian researchers from JICA. The distribution would further favour Asia if awards from AusAID were included in the analysis (accurate figures not available). When training attachment awards from JICA were excluded, the distribution of awards moved towards Africa: Asia 27 per cent, Africa 46 per cent and South America 27 per cent. Many of the larger funders were included in this analysis, but it should be noted that geographical information for the awards of the European Commission and BADC were not available.

Geographical proximity and historical links between countries, as well as a common language, appeared to be important influences on the focus of support by an organization. In some cases, distribution of awards was determined by a funding strategy to support particular countries or diseases. For example, TDR focuses its research capability strengthening grants mainly

on Africa and in least developed countries: 62 per cent of TDR Research Training Grants were awarded to African researchers (1995–98). Awards from JICA and AusAID were directed mainly to researchers in South Asia; support to Latin America was derived mainly from funding organizations based in the USA and Canada; and French and UK organizations tended to focus on specific countries in Africa (Francophone and Anglophone). Other factors likely to influence the distribution of awards include the existence of established collaborations, the ability of researchers to compete for funds, the availability of alternative local funds to support research, and the efficiency of advertising media.

2.3.5 Training mechanisms

The survey revealed that a variety of strategies are employed by funding agencies to deliver training to scientists in developing countries, although training is often linked to ongoing research programmes. Some agencies focus long-term support on a small number of centres in developing countries and train local scientists associated with these centres (e.g. IRD, the UK MRC, Wellcome Trust, CDC). Other agencies link training to competitively awarded larger scale programmes at a variety (but usually small number) of sites (e.g. NIAID, DANIDA, EC INCO-DC). Relatively few funders offer research training awards that are not restricted to specific sites or linked to other awards. The Wellcome Trust and TDR offer some possibilities in this respect, although many of their awards are also restricted.

Linking training to research projects that have received support through a competitive, peer-reviewed process provides some assurance that training will be in an appropriate intellectual environment. Concentrating resources at a limited number of centres also assists in building research facilities and a critical mass of people where high-quality science can flourish; avoiding wasteful dispersion of resources across unproductive sites. However, the selection of centres at which resources are focused is critically important and a number of key elements are required for successful research and training; for example the presence of talented scientific leaders, efficient administration, and local commitment to research (for a fuller discussion of effective research programmes and institutions see WHO, 1996, Chapter 7).

Many organizations target support for research and training on particular diseases, specific research disciplines or even individual training courses. For example, TDR programmes focus on eight target diseases, while the governments of Belgium, Norway and Germany support Master's training on selected courses specifically for participants from developing countries. NIAID and FIC offer some schemes that are open to all areas of biomedical sciences, while others aim to encourage research on particular diseases (e.g. tuberculosis) or in specific disciplines (e.g. reproductive biology, medical informatics). Similarly, the Wellcome Trust encourages research in specific areas (e.g. population studies, health services research and noncommunicable diseases), whilst also offering open schemes.

Many funding agencies support training in a developed country, usually in the country where the agency itself is based. A significant problem associated with overseas training of developing-country scientists is that trainees are often drawn away from their home countries to regions where the laboratory facilities and career prospects are far superior. For this reason funders often require an assurance from the home-country institute that a post will be available to a trainee following completion of an overseas training attachment. A recent internal review carried out by TDR (TDR, 1999) showed that only 4.5 per cent (6/131) of PhD graduates trained between 1991 and 1997 failed to return to their home country following training, thus indicating the success of the TDR approach.

There is also growing recognition that overseas institutes often cannot provide training that addresses a research problem of relevance to the student's home country or that is appropriate to the facilities and equipment in the home institute. The higher cost of training abroad is another factor that would favour exploring local or regional training options. Nevertheless, exposure of developing-country scientists to the research culture and high-quality training environments of laboratories abroad is still considered to be extremely valuable in training internationally competitive researchers. In the light of these issues, several funders support training in home institutes with attachments in a developed country (e.g. TDR, SAREC, DANIDA) and funders are beginning to make more use of local or regional training facilities where possible (TDR,

INCLEN and the Wellcome Trust for example).

There are currently few mechanisms that can link sites together within developing regions for multicentre studies or regional training networks. The European Commission INCO-DC programme, the MIM/TDR awards, SEAMEO-TROPMED and INCLEN are the most prominent in this respect.

2.4 CONCLUSIONS

The survey results showed the complex array of research training opportunities offered to developing countries by a broad range of funding organizations. This diversity of schemes presents difficulties to potential trainees attempting to identify and secure sources of funding. In addition, training opportunities are in many cases linked to larger research programmes and are not offered openly.

In general, training schemes are dispersed and fragmented with the majority of funders providing relatively few awards annually and only a small number of organizations providing larger-scale training programmes. Few developed countries include a strong commitment to research capacity building as an integral element of their overseas development programmes. Furthermore, there appear to be few opportunities for scientists to develop their research careers through the funding schemes of a single organization, as support from most organizations tends to be targeted at one particular level.

Available data suggest that Africa and Asia are slightly favoured over South America in terms of the availability of training awards. Overall, it was evident that the location of training is strongly influenced by mechanisms of bilateral support, and by historical and language associations between countries. The majority of training is offered overseas, often in the country of the donor organization, and training partnerships tend to link specific developed countries to particular regions or countries. The establishment of funding mechanisms that can support more diverse training links would assist in optimizing the use of the best training centres globally and in promoting greater diversity in collaborations, for example amongst Francophone and Anglophone African countries. Additional funding mechanisms to support networks and multicentre studies are also required to allow regional technology transfer and sharing of resources. This is an issue that has been recognized by the Multilateral Initiative on Malaria, and some progress has already been made in establishing schemes to support multi-centre studies and networks across Africa (e.g. the MIM/TDR awards).

Training attachments and short courses are the predominant type of training provided by organizations in developed countries. Very few organizations provide support for undergraduate training. Nearly three-quarters of organizations surveyed provide Master's awards and just over half offer PhD training. However, over 50 per cent of Master's awards came from two organizations and over 90 per cent of identified PhD awards came from four organizations. Postdoctoral training is often provided in association with larger research programmes and few agencies provide opportunities for individual scientists to apply for independent research support.

Training offered by funders is often linked to large research programmes or targeted at particular diseases, disciplines or courses. The balance of research expertise generated in different subject areas will obviously be strongly influenced by these approaches to training. There is therefore a need for a mechanism that allows a strategic overview of ongoing activities, which will assist in matching research efforts to actual health needs and disease burden.

Even after taking into consideration the inevitable underestimation in the survey results, the data suggest that investment by higher-income countries in training biomedical scientists in developing countries is low relative to training activities in industrialized countries. In 1997, the UK spent US$145 million[5] on training and fellowships to develop UK expertise in biomedical research, compared with a figure in the present study of about US$100 million in the same year for training scientists across Africa, Asia and South America; regions with an aggregate population of about 75 times that of the UK. Similarly, the 684 PhD awards to developing-country scientists identified for the four years 1995–98 compares with at least 2101 PhD awards in biomedicine and health in the UK in a single year (1995, supported by the UK Government-funded Medical Research Council and the Biotechnology and Biological Sciences Research Council). Despite the small overall

[5] In 1997 UK Medical Research Council expenditure on training awards and fellowships (Master's and PhD studentships; junior to senior fellowships) was approximately US$52 million; Biotechnology and Biological Sciences Research Council expenditure on studentships and fellowships was US$37.8 million; Wellcome Trust expenditure on postdoctoral fellowships (mid-level and training) was US$45 million and approximately US$10 million was spent on PhD studentships.

investment, there was a marked increase in expenditure over the survey period, suggesting a growing commitment by organizations in high-income countries to support training of scientists from developing countries.

The above figures need to be considered in the light of the more limited educational bases in developing countries at undergraduate level, and hence the availability of individuals to absorb training at doctoral level. The extent of higher education varies considerably between countries. For example in Africa the number of tertiary students per 10 000 population in 1991 ranged from two to four for Ethiopia, Malawi, Tanzania and Uganda, through 30–50 for Congo, Kenya, Nigeria and Zimbabwe, and up to 80 for South Africa. By comparison, the equivalent figures for China and Japan were 19 and 238 respectively (African Development Bank, 1994). Thus, it might be approximated that there are 10–100 times more tertiary students per unit population in industrialized countries as compared with developing countries. The figures for PhD awards obtained in the present study indicate that there are approaching 1000 times more awards per unit population in the UK than in the developing regions combined. Although these figures encompass a range of different educational systems across the developing world and involve a lack of precision, they do indicate the disparity in the numbers of scientists trained in high- and low-income countries in relation to population sizes; particularly if the dependence of developing countries on external support for postgraduate training is taken into consideration. The figures on numbers of tertiary students relative to numbers of PhD awards also suggest that there is additional capacity to absorb PhD training in some lower-income countries.

An important observation in the present study is that relatively few organizations actively track the levels of training that they provide and the success of their schemes: only 13 out of the 39 organizations that responded to the survey were able to provide full data. Many do not maintain accurate central records, particularly when training is provided as part of large research programmes. This observation underscores the fragmented nature of current approaches to training scientists in developing countries and the need for a more concerted approach. The results of this study would support a call for greater international effort to monitor and review the effectiveness of current schemes in building productive scientific research capability in lower-income regions of the world.

In view of the enormity of the challenge in building research capacity in developing countries, funding organizations face some difficult decisions concerning where best to direct their resources for maximal effect. The data gathered in the present survey provides essential information on the international context against which such decisions can be made.

Outputs of malaria research 3

The number of published papers is an indicator of research output that can provide a proxy measure of research activity in a particular field. More detailed characterization of publications yields information on key research centres, international collaboration patterns and strengths and weaknesses in different subfields of research. The present chapter uses this approach to assess the current status of African malaria research activity, set against the background of international activity. Publication analyses are, however, limited in their scope and this chapter therefore also explores the use of national malaria treatment guidelines and policies to make an assessment of the influence of malaria research in developing policies for disease treatment and control. Similar future analyses of these indicators will enable changes in research status to be monitored, providing mechanisms for evaluation of the broad success of schemes aimed at strengthening research capability in Africa.

3.1 BACKGROUND

Evaluation of the results of biomedical research can be approached in a number of different ways and each approach is able to provide a specific insight into scientific activity. Methodology therefore needs to be tailored to the particular assessment being carried out. The limited scope of current indicators, however, means that a combination of approaches is required to obtain a more complete view of scientific activity and its social, economic and cultural impacts.

Analysis of publication outputs in international databases (bibliometrics) or analysis of commercial patents are standard approaches to assess direct output from scientific activity (Narin, 1994; Dawson *et al.*, 1998). Published papers represent relatively accessible and convenient measures of research activity which broadly equate with advances in knowledge. Although numbers of papers provide measures of the volume of research outputs, they cannot indicate the quality of these outputs or the ultimate impact of research on policy development and on health. Patents are another accessible measure which provide indicators of technological potential at the frontiers of knowledge.

The present study selected bibliometric approaches to assess the current status of malaria research activity in Africa. The results, however, necessarily reflect the databases used for the analyses. Currently available databases concentrate on papers published in international, peer-reviewed journals, and cannot capture information published in local sources, the so-called 'grey literature' (e.g. ministry of health publications, technical memoranda or conference proceedings). The omission of this grey literature is a major constraint, particularly when evaluating research of relevance to malaria-endemic countries, and when examining links between research and implementation. This chapter therefore gives an insight only into publication performance as represented in the international, predominantly English-language scientific literature.

Assessments of longer-term outcomes of research, such as the development of new products to fight disease or improvements in healthcare, require more complex approaches. In this study, references cited in malaria guidelines and policies in African countries were examined to make a more direct assessment of the degree to which both published and unpublished papers have been incorporated into policy and practice. Policies and guidelines are resources aimed at health professionals and disease control personnel which are intended to influence or direct clinical practice and approaches to preventing disease. Reference to a scientific paper in a policy or guideline therefore demonstrates a link between a research study and policy development, and provides an indication of the practical utility of the research results reported in the paper.

3.2 METHODS

3.2.1 Overview of bibliometric analyses

The current assessment of malaria research in Africa employed a number of different bibliometric approaches.

1. Numbers of publications were used as a quantitative measure of research activity at different levels: internationally, within Africa, at individual country level and at specific research centres.
2. Author addresses were used to explore patterns of international collaboration.
3. Classification of papers into defined subfields of malaria research provided information on the balance of global and African activity across different disciplines, and on the research focus of individual research centres.
4. Funding acknowledgements quoted in publications were used to analyse sources of financial support for research.
5. Journal impact factors were used to assess the potential impact of publications.

The combination of approaches aimed to provide a detailed insight into the characteristics of research ongoing in Africa in the context of international activity.

3.2.2 Databases and search strategy

The databases used for the bibliometric analysis were the Science Citation Index (SCI) produced by the Institute for Scientific Information in Philadelphia, and MEDLINE, produced by the US National Library of Medicine. MEDLINE covers a more comprehensive set of journals relating to medical research, particularly journals reporting on clinical and epidemiological studies. It also has better coverage of local, regional and non-English language journals. SCI has greater coverage of basic chemistry and drug development studies, but is primarily based on English language journals and therefore is biased towards the USA and Europe (Sancho, 1992). This bias will have particular significance in the field of malaria, which predominantly affects developing countries and is of local interest to researchers in those countries. A major advantage of SCI is that it provides multiple author addresses, enabling analysis of international collaboration patterns. MEDLINE records only the address of the first author, precluding its use in analysis of co-authorship on publications. However, MEDLINE includes abstracts that assist in assessment of the specific research focus of publications.

The search strategy employed was that used in a previous review of malaria research activity (Anderson *et al.*, 1996)(Annex 3). Specific keywords relating to malaria were used to search the titles of publications in SCI and MEDLINE databases for the three-year period 1995–97. This time period was chosen in order to obtain the most up-to-date information on malaria research activity. Articles, notes and reviews were included in the analysis as these are generally considered to contain substantial scientific material, but letters (apart from those to *Nature*), meeting reports, news and editorials were excluded.

The broader field of tropical medicine was defined by a similar process (Lewison, 1996). The definition aimed to capture all publications relevant to health and disease in developing countries. Publications were retrieved from SCI for the period 1995–97 in order to compare the outputs in the field of malaria with the wider field of tropical medicine.

3.2.3 National outputs and collaboration patterns

Author addresses on malaria publications were used to determine the outputs of individual countries and to identify the most prolific research institutes in Africa. For publications recorded in the SCI database, addresses of all authors were used. For MEDLINE, however, only first author addresses were available – a limitation which means that the contribution of countries and institutions not associated with first authors is missed. Addresses were analysed using integer counts, such that one count was assigned for each paper with at least one address from a specific country. Thus, the figures represent the numbers of publications in which a country has participated, rather than the number exclusively produced by that country. Author addresses on SCI publications were also used to examine co-authorship on malaria publications and hence patterns of international collaboration. Collaboration patterns were examined for the highest publishing countries worldwide and countries in Africa.

3.2.4 Research categories

To examine the levels of research activity in different areas of malaria research, and to identify regional, country- and institute-specific research strengths, publications retrieved from SCI and MEDLINE were classified into a series of subfield categories. The classification system employed was that developed for a previous review (Anderson *et al.*, 1996) and is shown in Annex 6. Malaria research publications were categorized by inspection of the title, and where possible, on the basis of information in the abstract. Precise definition of research categories reduced the number of papers spanning more than one category, although separation of smaller categories of biology, biochemistry and genetics of *Plasmodium* was difficult. Each paper was also classified as either 'human' if it involved studies of malaria in humans, or 'non-human' if it described studies in animals or *in vitro* models.

3.2.5 Funding acknowledgements

Financial support for published research was analysed using acknowledgements to funding bodies on papers and institute addresses (to identify intramural support e.g. from government or industry). Acknowledgements and/or institute addresses for each malaria publication were obtained by examining individual papers in libraries.

3.2.6 Impact of research

The potential impact of a paper (W), based on recent average citation impact data for journals, was calculated using the methodology outlined by Dawson *et al.* (1998) for both the international and African data sets. High W values reflect a higher potential impact; the range is from 1 to 4.

Papers were also assigned a research level value (RL) determined by the clinical or basic nature of the journals in which they were published. RL1 journals describe clinical observation, whilst RL4 journals report basic science.

3.2.7 Malaria guidelines and policies

The references in ministry of health guidelines and policies from selected countries in Africa were examined to assess the types of data on which they were based, for example, whether they incorporated information from recent malaria research publications and publications emanating from the specific country concerned.

3.3 RESULTS

Unless otherwise stated all results are based on publications in both SCI and MEDLINE.

3.3.1 Global and African malaria research outputs

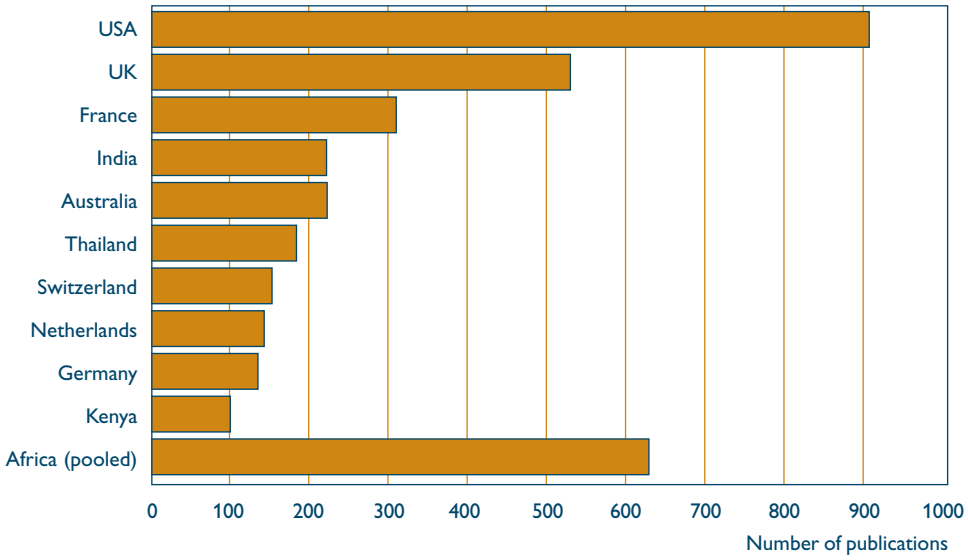
A total of 3672 malaria papers were retrieved from the SCI and MEDLINE databases for the years 1995–97. There was an increase in the number of malaria papers published internationally, from 1121 in 1995 to 1295 in 1997. However, there does not appear to be a steady upward trend as the equivalent 1994 figure was 1302 (Anderson *et al.*, 1996).

There was a considerable degree of overlap in publications in the MEDLINE and SCI databases. Malaria research papers were published in a total of 568 journals across the two databases, with 119 journal titles specific to SCI and 153 titles specific to MEDLINE. A greater number of non-English language and local journals appeared in MEDLINE (e.g. *Santé*, *Central African Journal of Medicine*, *West African Journal of Medicine*, *Tropical Doctor*). Of the 3672 malaria papers identified, 2869 (78 per cent) papers were included in SCI and 3211 (87 per cent) in the MEDLINE database.

Over the same period, 13 815 papers in the field of tropical medicine were identified internationally in the SCI database, with malaria papers constituting 20.8 per cent of the total output in tropical medicine.

3 Outputs of malaria research

Figure 3.1 Top publishing countries in malaria research 1995–97.



A total of 633 malaria research papers published between 1995 and 1997 included at least one author address in Africa. This represents 17.2 per cent of the global malaria research output over the three-year period. In 329 papers (52 per cent), the first author address was in Africa. Of the African output, 121 papers were found only in SCI, while 112 papers were found only in MEDLINE. Malaria research output from Africa remained fairly constant, with 201 papers published in 1995 and 215 papers in 1997.

Analysis of address information recorded on malaria papers from both SCI and MEDLINE revealed the leading publishers over the period 1995–97 (Figure 3.1). The USA participated in the greatest number of malaria publications, followed by the UK and France. Although the USA remains the top malaria-publishing country, its share of international outputs has decreased from 37 per cent for the years 1984, 1989 and 1994 (Anderson *et al.*, 1996) to 30 per cent in 1995–97 (SCI database only). The UK and French contributions to malaria publications have remained steady since 1994. The malaria-endemic countries India, Thailand and Kenya have a notably high share of global malaria publications.

Table 3.1 illustrates country contributions to international malaria research relative to performance in the overall field of biomedicine. All of the top ten publishing countries, with the exception of the USA and Germany, contribute relatively more to international malaria research than to overall biomedical research. Thailand and Kenya have particularly high commitments to malaria research, as does Africa as a whole. Although Africa contributes 17.2 per cent of world malaria publications, it participates in only 1.2 per cent of all biomedical publications.

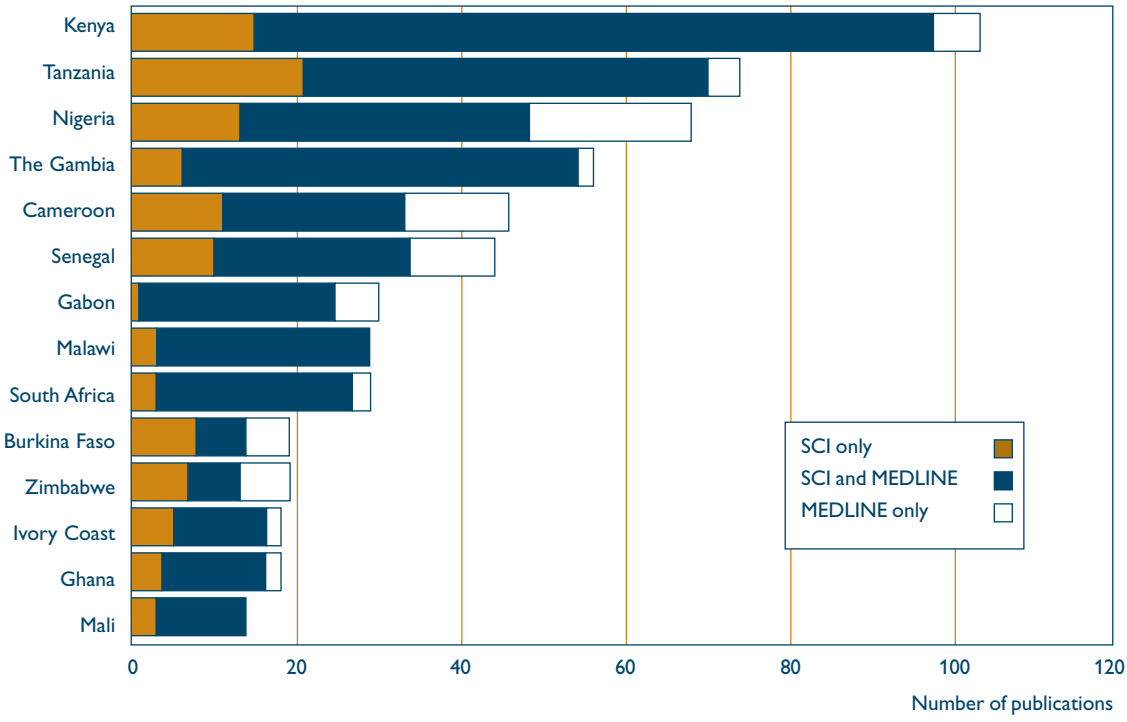
Figure 3.2 shows sub-Saharan African countries that published 14 or more malaria research papers over the three-year period. A complete list of publication output by African country is given in Annex 4. These data include all publications with an address in Africa and no attempt was made to separate African and expatriate researchers.

Table 3.1 Country contributions to international publication outputs.

Country	Percentage (%) of world malaria publications 1995–97	Percentage (%) of world biomedical publications 1995–97 (Dawson *et al.*, 1998)	Share of world malaria publications relative to share of world biomedical publications*
USA	30.0	41.7	0.7
UK	17.8	10.5	1.7
France	9.6	6.2	1.5
Australia	7.3	2.6	2.8
Thailand	5.5	0.2	27.5
Switzerland	5.2	2.0	2.6
India	4.6	1.0	4.6
Netherlands	4.6	3.4	1.4
Germany	4.0	7.8	0.5
Kenya	3.2	0.1	32.0
Africa (pooled)	17.2	1.2	14.3

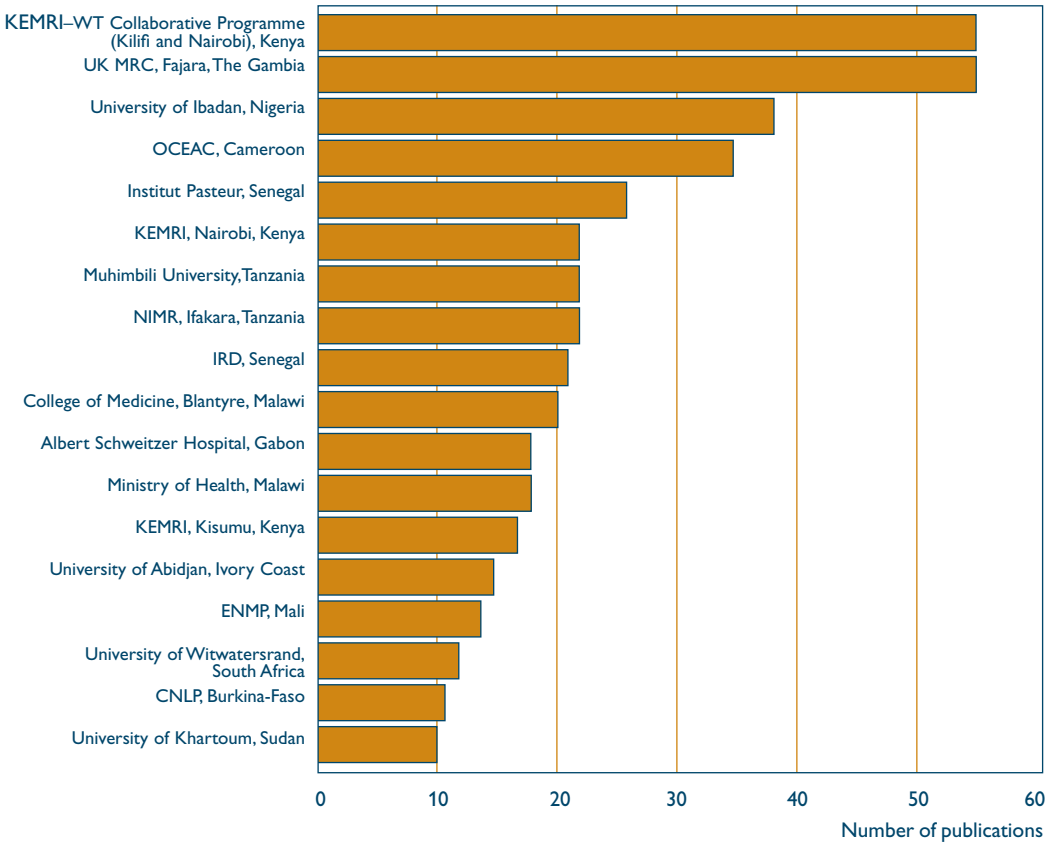
* A value greater than 1 indicates a greater contribution to world malaria research publications relative to overall biomedical research

Figure 3.2 Top African countries publishing in malaria research 1995–97.



3 Outputs of malaria research

Figure 3.3 Highest publishing malaria research centres in Africa, 1995–97.



CNLP Centre National de Lutte contre le Paludisme
ENMP École Nationale de Médecine et de Pharmacie et d'Ontosomatologie
IRD Institut de Recherche pour le Développement (formerly ORSTOM)
KEMRI Kenyan Medical Research Institute
MRC Medical Research Council
NIMR National Institute for Medical Research
OCEAC Organization de Coordination pour la Lutte contre les Endémies en Afrique Centrale
WT Wellcome Trust

Address details are provided in Annex 12

Figure 3.4 Regional collaborations in malaria research 1995–97 (SCI).

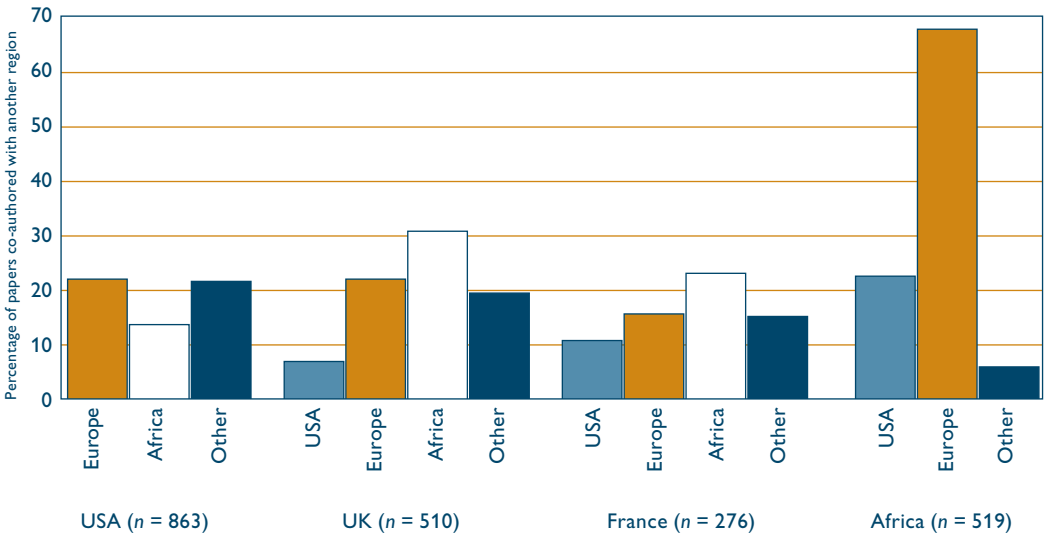
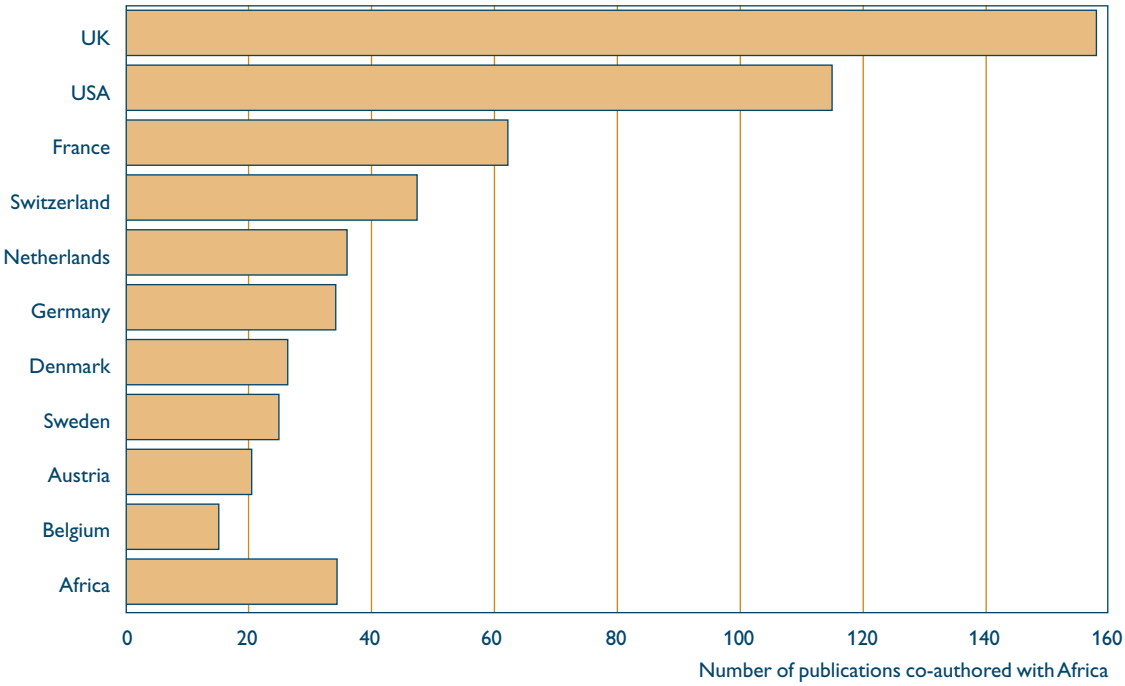


Figure 3.5 Leading collaborators with Africa in malaria research, 1995–97 (SCI).
Total number of publications with an African address = 519



Further examination of author addresses identified the individual institutes in Africa with the highest publication outputs (Figure 3.3). Eighteen African centres published ten or more malaria papers in the three-year period analysed. The joint highest publishing institutes were The UK Medical Research Council Laboratories, Fajara, The Gambia, and the Kenyan Medical Research Institute (KEMRI)–Wellcome Trust Collaborative Programme (Kilifi and Nairobi), Kenya, followed by the University of Ibadan, Nigeria, and Organization de Coordination pour la Lutte contre les Endémies en Afrique Centrale (OCEAC), Yaoundé, Cameroon. Most of the institutes collaborated extensively outside their own country, with the exception of the Universities of Ibadan and Witwatersrand.

3.3.2 International collaboration in malaria research

Analysis of co-authorship on SCI malaria publications revealed that 40 per cent of publications containing USA author addresses involved a collaboration with another country, compared with figures of 55 per cent for the UK and 53 per cent for France. African papers showed a high level of international co-authorship, with 79 per cent involving a collaboration outside Africa.

Africa has particularly strong collaborative links with Europe: 68 per cent of its publications were co-authored with a European country and 22 per cent with the USA (Figure 3.4). However, collaborations between African countries were rare, with only 34 publications (6.5 per cent) containing more than one African address. The actual level of collaboration across Africa may be higher, however, as this co-authorship analysis was restricted to SCI, which focuses on European and US journals and omits most local and regional journals from Africa. UK and France both collaborated more frequently with Africa than with other European countries, while the USA collaborated more extensively with Europe than with Africa.

Analysis of the countries with which Africa collaborates revealed that the UK, followed by the USA and France are the most frequent collaborators (Figure 3.5).

Figure 3.6 Collaboration patterns of top malaria publishing countries, 1995–97 (SCI).
Non-African and African countries collaborating most frequently with the USA, UK and France

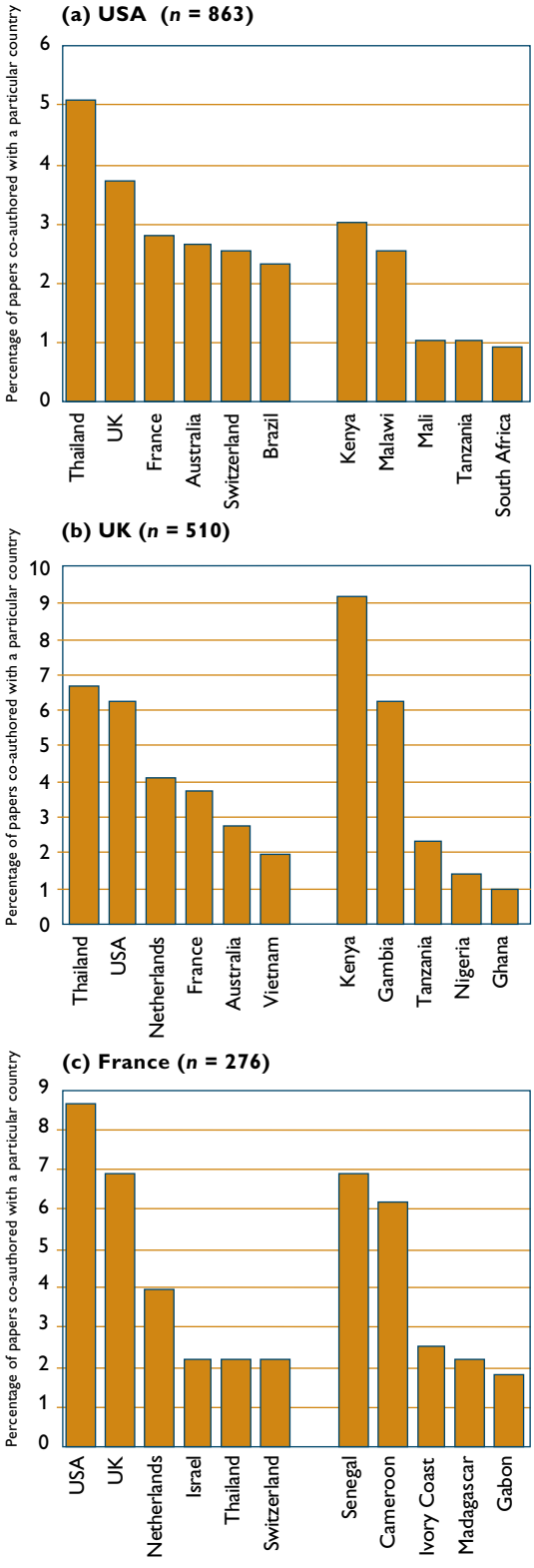


Figure 3.7 Collaborations of African countries in malaria research 1995–97 (SCI).

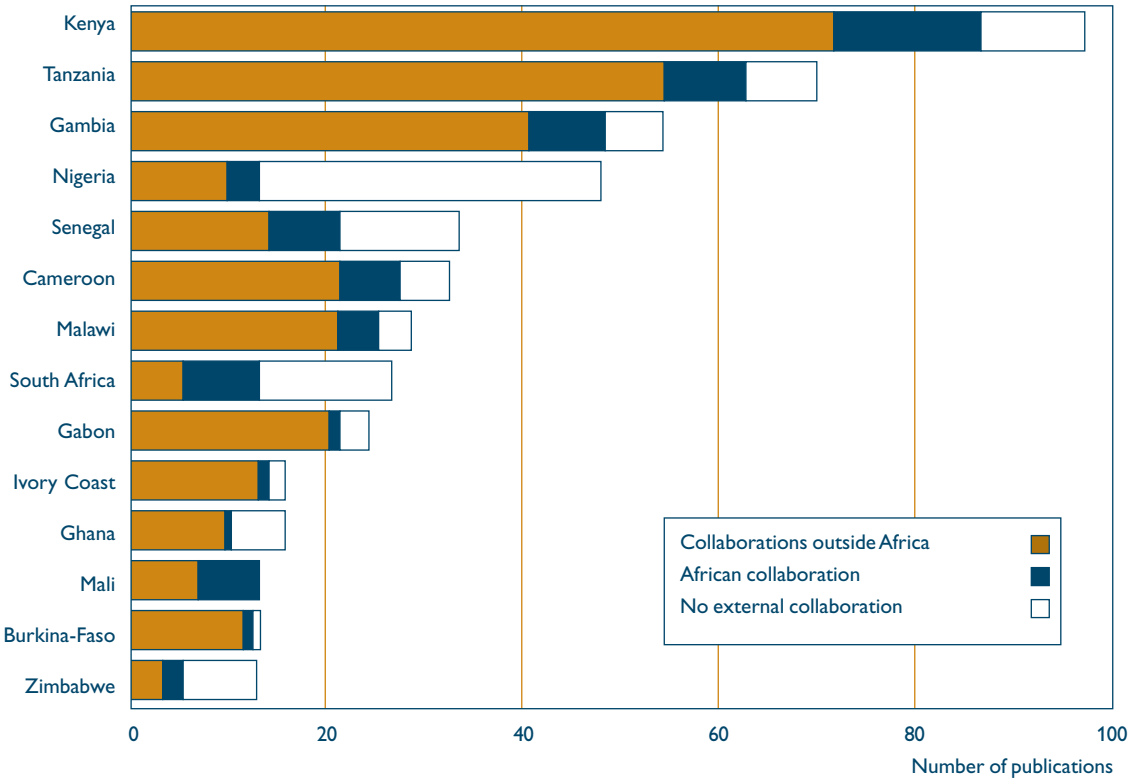
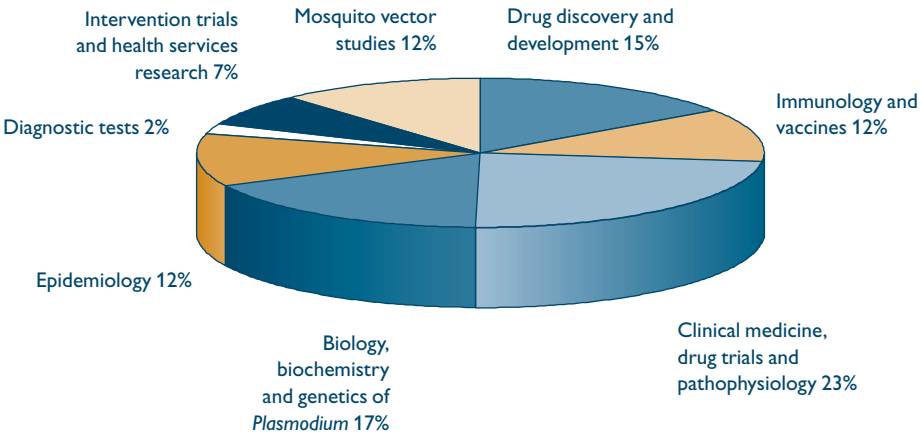


Figure 3.6 shows the country-wise collaboration patterns of the top three publishing countries in malaria research: the USA, UK and France. There was little overlap in the principal African collaborating partners of these countries indicating that a common language, as well as historical links, are important determinants of patterns of collaboration.

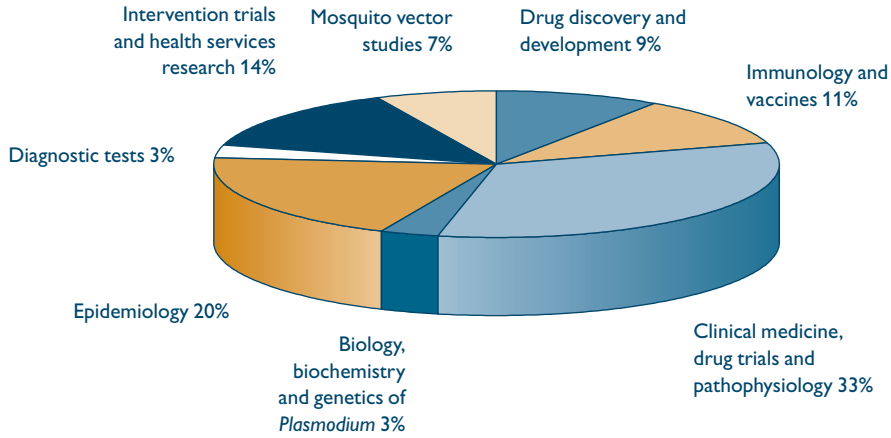
Examination of co-authorship patterns for individual African countries confirmed that most countries participated in a high level of collaboration outside Africa, with few collaborations across Africa (Figure 3.7). However, country-specific variations in collaboration patterns were observed: Nigeria and South Africa produced a higher proportion of papers without any external collaborations.

Figure 3.8 Malaria research publications (1995–97) by major research category (SCI and MEDLINE).

(a) International malaria publications (*n* = 3672)



(b) African malaria research publications (*n* = 633)



3.3.3 Research categories

The distributions of both international and African papers across broad categories of malaria research are shown in Figure 3.8. Only 0.7 per cent of papers were judged to span more than one discipline. Internationally, the category with the greatest number of publications was clinical medicine, drug trials and pathophysiology with 23 per cent of publications, followed by biology, biochemistry and genetics of *Plasmodium* with 17 per cent. Comparison of the international output in 1995–97 with a previous review of papers published in 1984, 1989 and 1994 (Anderson *et al.*, 1996) revealed that there has been very little change in the relative activity of the different subfields.

The emphasis of research in Africa was on clinical and field studies: publications were most numerous in the category clinical medicine, drug trials and pathophysiology (33 per cent), followed by epidemiology (20 per cent) and intervention trials and health services research (14 per cent). Studies of the biology, biochemistry and genetics of *Plasmodium* accounted for only 3 per cent of total output. Similarly, fundamental studies of mosquito vectors or vector taxonomy, ecology or behaviour accounted for 7 per cent of African papers, compared with 12 per cent for the international set. About a quarter of African epidemiological studies focused on mosquitoes (5 per cent of the total set). Nine per cent of papers described studies on

drug discovery and development in animal models or *in vitro*; the majority of these relating to testing of natural products for antimalarial activity.

The category of intervention trials and health services research was well represented in the African set of papers (14 per cent of the total), but was less significant in the international set (7 per cent of total). About half of the African papers in this category focused on social, cultural or economic aspects of malaria treatment or control measures. It should be noted, however, that not all research relevant to these areas will have been captured by the databases employed, and the use of the Social Sciences Citation Index database might have extended coverage.

Internationally, 46 per cent of papers described studies of malaria in humans, whereas the equivalent figure for Africa was 81 per cent.

In drawing conclusions from these results it should be borne in mind that the research effort represented by a single paper varies between subfields due to differences in experimental approaches and techniques. In addition, the extent of the subfield, which is determined by the definition employed to describe it, will also affect the absolute number of publications per subfield. Finally, the overall field of malaria research is relatively small and individual research groups may substantially influence output in a particular subfield and hence the balance between subfields.

3.3.4 Funding acknowledgements

Table 3.2 shows the number of malaria papers in the SCI and MEDLINE databases that were retrieved from UK libraries and examined for funding acknowledgements. Of the 2724 international papers examined, 75 per cent acknowledged at least one funding agency. In the African data subset, 82.2 per cent of the papers located had at least one funding acknowledgement.

As the search was restricted to UK libraries, it is possible that journals published in English were more readily available than those in other languages, resulting in a bias towards funders of English-speaking researchers. Furthermore, in interpreting funding acknowledgements data, it should be noted that the results can only serve as an indicator of support provided by funding bodies, and they do not necessarily reflect the actual expenditure. The numbers of acknowledgements will be influenced by the degree of emphasis placed on researchers acknowledging their funders, and the specific funding strategies employed by organizations. A funding body may, for example, choose to provide partial funding for a project, or to provide the full costs as far as possible. Moreover, some agencies provide infrastructure costs for research institutes, whereas others do not. Counts of funding acknowledgements do not take into account these differing levels of support, nor do they recognize funders that have contributed through other agencies.

Table 3.2 Number of funding acknowledgements on malaria publications 1995–97.

	Total malaria papers in SCI and MEDLINE searches	Papers located during physical search of libraries	Papers with funding acknowledgements
International malaria papers	3672	2724	2034
African malaria papers	633	499	410

Table 3.3 shows the funding organizations most frequently acknowledged in the international and African sets of malaria papers (Annex 7 gives additional details). Internationally, TDR received the highest number of funding acknowledgements, followed by the Wellcome Trust, the US Department of Defense and NIAID. In the African papers, TDR was again the most frequently acknowledged funder, with 24 per cent of all papers containing at least one acknowledgement, followed by the Wellcome Trust (19 per cent), KEMRI (17 per cent) and the UK Medical Research Council (15 per cent).

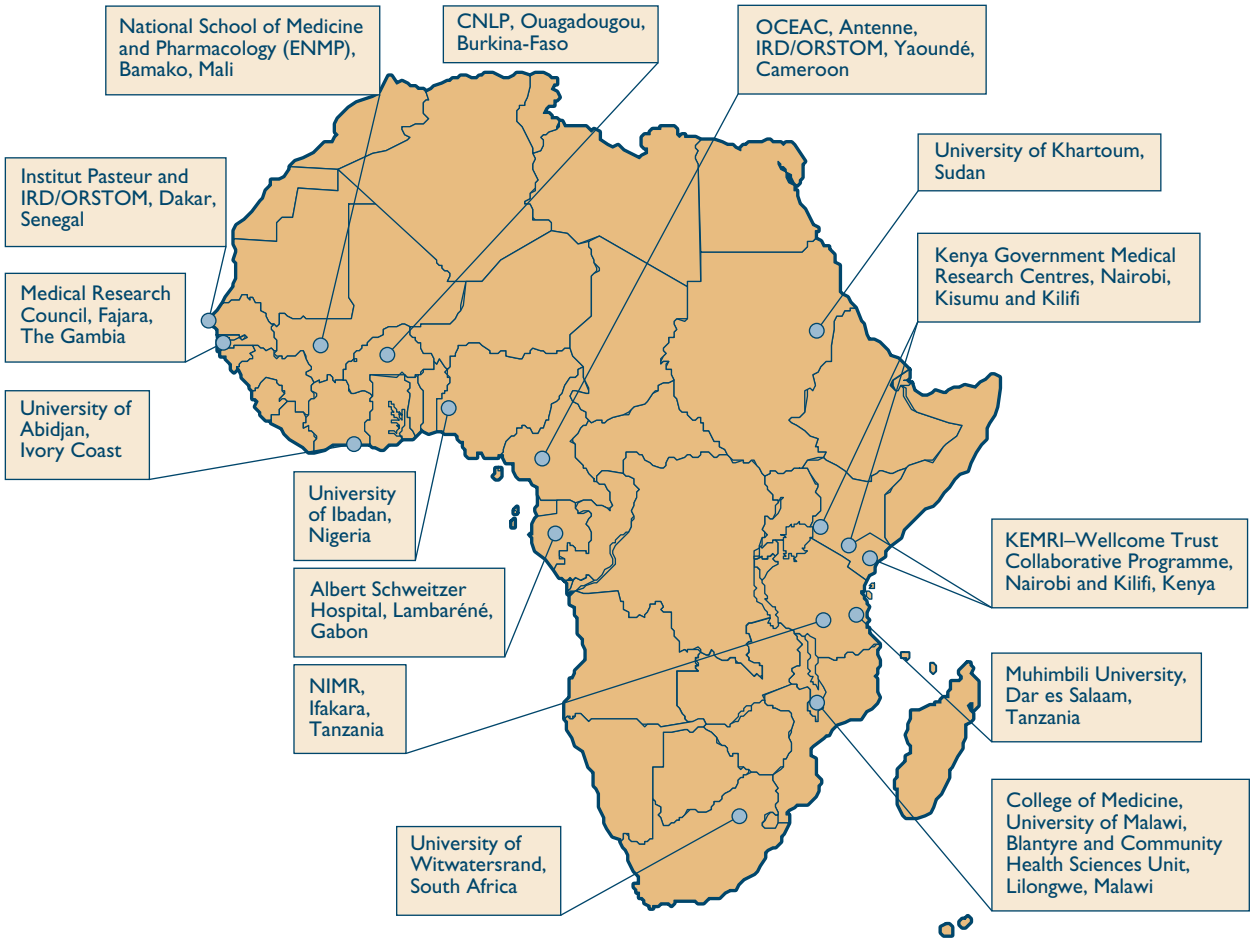
TDR was also the most frequently acknowledged funder in a previous analysis of international malaria publications from 1984, 1989 and 1994 (Anderson *et al.*, 1996) accounting for 23 per cent of all acknowledgements. However, the TDR share of acknowledgements decreased to 19 per cent in the current analysis. NIAID, the second ranked funder in terms of acknowledgements in the earlier survey also appears to have decreased its share from 17 per cent to 9 per cent. These figures may, however, be influenced by the acknowledgement practices of authors in the use of NIH and NIAID (NIAID being one of the institutes of NIH). NIH received only 2 per cent of acknowledgements in the earlier survey compared with 8 per cent in the current survey. Overall, 353 papers (17 per cent) acknowledged either NIH or NIAID. The Wellcome Trust and the European Commission both increased their percentage share over the period of the two surveys. Funding from French sources was noted to be distributed across a range of organizations, particularly governmental agencies. The number of papers with an acknowledgement to at least one of these agencies totalled 221 for the international set and 64 for Africa, thus confirming the substantial support from France overall. One African governmental source, the Kenyan Medical Research Institute, featured strongly as a funder in the African set of papers. The governments of Cameroon, Tanzania, Burkina-Faso, The Gambia, Ethiopia and Malawi received smaller numbers of acknowledgements.

Table 3.3 Acknowledgements to funding bodies, 1995–97.

International			African		
Funding body	Number of papers with at least one acknowledgement	(% of total)	Funding body	Number of papers with at least one acknowledgement	(% of total)
UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR)*	388	(19%)	Special Programme for Research and Training in Tropical Diseases (TDR)	97	(24%)
Wellcome Trust	234	(12%)	Wellcome Trust	79	(19%)
US Department of Defense	231	(11%)	Kenya Medical Research Institute (KEMRI)	71	(17%)
National Institute of Allergy and Infectious Diseases (NIAID)	184	(9%)	UK Medical Research Council	63	(15%)
National Institutes of Health (NIH)	169	(8%)	Centers for Disease Control and Prevention (CDC USA)	39	(10%)
UK Medical Research Council	160	(8%)	Institut de Recherche pour le Développement (IRD) formerly ORSTOM	35	(9%)
European Commission	141	(7%)	US Agency for International Development (USAID)	33	(8%)
Centers for Disease Control and Prevention (CDC USA)	115	(6%)	World Health Organization (WHO)	33	(8%)
US Agency for International Development (USAID)	107	(5%)	Swiss Tropical Institute	31	(8%)
Institut Pasteur	103	(5%)	US Department of Defense	28	(7%)

*Many funders contribute to TDR and these are not acknowledged individually (see Annex 1 for details of contributions to TDR in 1989–98)

Figure 3.9 Location of malaria research centres in Africa publishing more than ten papers in 1995–97.



Only two commercial sources of support, Hoffman La Roche and SmithKline Beecham, were prominent in the three-year period analysed (58 and 29 papers respectively). Similar earlier analysis (Anderson *et al.*, 1990) had shown involvement of the Wellcome pharmaceutical company (now Glaxo Wellcome plc), but their activities in malaria research have now been reduced.

3.3.5 Characterization of top research institutes in Africa

The top publishing institutes across Africa are well balanced in their distribution between East and West Africa, but the published output from southern (excluding South Africa) and particularly central Africa is low (Figure 3.9).

Table 3.4 summarizes the major research specializations and primary sources of funding for the top publishing African malaria research institutes in 1995–97.

Subfield analysis indicated that many institutes conduct multidisciplinary research programmes: four institutes publish research in five or more malaria research subfields, and the majority of institutes publish research in at least three subfields, with the exception of the Ministry of Health, Malawi; University of Abidjan, Ivory Coast, and CNLP, Burkina-Faso where research publications are predominantly focused on a single subfield. In reflection of the overall publications portfolio of Africa, ten of the 14 top publishing institutes and research centres

Table 3.4 Research specializations and funding acknowledgements at top publishing African malaria research centres.

Centre *n* = number of malaria publications in SCI and MEDLINE (1995–97)	Specialities	Three most frequently acknowledged sources of funding (ranked by number of acknowledgements)*
KEMRI–Wellcome Trust Collaborative Programme, Kilifi/Nairobi, Kenya (*n* = 55)	**Antimalarial drug trials:** Lapdap; artemether; quinine; pharmacokinetics and pharmacology **Pathophysiology:** severe malaria symptoms and clinical observations **Epidemiology:** link between transmission and disease **Intervention trials:** bed net trials, and reduction of morbidity and mortality **Molecular biology** **Health services research/social sciences**	KEMRI Wellcome Trust TDR
MRC Laboratories, Fajara, The Gambia (*n* = 55)	**Immunology and vaccine development:** characterization of immune response to parasite antigens; SPf66 vaccine trials **Clinical management of malaria and antimalarial drug trials:** iron therapy studies; drug trials in humans **Epidemiology:** human genetics in relation to malarial disease **Intervention trials:** insecticide-treated nets (ITNs) **Pathophysiology:** parasite adhesion, clinical markers and disease outcomes	UK MRC Wellcome Trust TDR
University of Ibadan, Nigeria (*n* = 38)	**Clinical management and antimalarial drug trials:** pharmacokinetics and disposition of antimalarials in humans; artemether, mefloquine, quinine drug trials **Pathophysiology and disease symptoms of malaria:** clinical diagnosis and observation **Immunology:** longitudinal seroreactivity studies in humans	TDR Wellcome Trust Swedish MRC/ Swedish Institute
Organization de Coordination pour la Lutte contre les Endémies en Afrique (OCEAC), Yaoundé, Cameroon (*n* = 35)	**Immunology and vaccine development:** humoral and cellular immune responses to parasite antigens **Epidemiology:** mosquito behaviour in relation to transmission and mosquito–parasite interactions **Studies of malaria mosquito vectors** **Malaria in pregnancy:** intervention trials and immunology **Antimalarial drug trials:** including phospholipid metabolism inhibitors	ORSTOM (IRD) French Ministry of Cooperation Cameroon Government
Institut Pasteur, Dakar, Senegal (*n* = 26)	**Immunology:** immune responses in human communities **Studies of malaria mosquito vectors:** mosquito genetics **Epidemiology:** clinical presentation and incidence under different transmission levels; population genetics of *Plasmodium falciparum*	Institut Pasteur ORSTOM (IRD) French Ministry of Cooperation
KEMRI, Nairobi, Kenya (*n* = 22)	**Clinical management of malaria and antimalarial drug trials:** field trials; screening plant compounds **Intervention trials:** mosquito vector control (repellents; ITNs) **Studies of malaria mosquito vectors:** population genetics and gene flow in *Anopheles gambiae*	KEMRI CDC TDR US DOD
Muhimbili University, Dar es Salaam, Tanzania (*n* = 22)	**Health services research:** role of traditional healers; community treatment practices; community perception of malaria, particularly in pregnant women **Clinical management of malaria and antimalarial drug trials:** biochemical predictors of severe disease; artemesinin drug trials	USAID Sida/SAREC US DOD

Table 3.4 Research specializations and funding acknowledgements at top publishing African malaria research centres (cont.).

Centre *n* = number of malaria publications in SCI and MEDLINE (1995–97)	Specialities	Three most frequently acknowledged sources of funding (ranked by number of acknowledgements)*
National Institute for Medical Research (NIMR), Ifakara, Tanzania (*n* = 22)	**Epidemiology:** malaria transmission by mosquitoes, particularly infectivity. Studies of malaria mosquito vectors: biology and ecology **Immunology and vaccine trials**: field trials of SPf66; immunological markers of fevers in humans	Swiss Tropical Institute Swiss Directorate for Technical Cooperation and Humanitarian Aid TDR
Institut de Recherche pour le Développement (IRD) (Formerly ORSTOM) Dakar, Senegal (*n* = 21)	**Epidemiology:** malaria transmission intensity and clinical incidence; population genetics of *P. falciparum;* vector behaviour and transmission **Studies of malaria mosquito vectors:** ecology and population genetics	ORSTOM (IRD) Institut Pasteur French Ministry of Cooperation
College of Medicine, University of Malawi, Blantyre, Malawi (*n* = 20)	**Clinical management of malaria and antimalarial drug trials** **Intervention trials and health services research:** economics of malaria control **Malaria in pregnancy:** epidemiology of infection; intervention trials, health services research, including maternal practices	WHO CDC USAID
Albert Schweitzer Hospital, Lambarene, Gabon (*n* = 18)	**Antimalarial drug trials:** combination chemotherapy using antimalarials with antibiotics **Pathophysiology:** TNF and nitrogen oxides with severe symptoms and rapid clearance	TDR DAAD German Academy of Sciences
Ministry of Health, Lilongwe/Blantyre, Malawi (*n* = 18)	**Intervention trials and health services research**	CDC, USAID Malawian Government
KEMRI, Kisumu, Kenya (*n* = 17)	**Epidemiology:** mosquito behaviour and ecology in relation to malaria transmission **Intervention trials:** mosquito vector control (repellents; ITNs) **Molecular biology** **Studies of malaria mosquito vectors** **Clinical management of malaria and antimalarial drug trials** **Immunology:** immune responses to and characterization of *P. falciparum* antigens	KEMRI CDC US DOD TDR
University of Abidjan, Ivory Coast (*n* = 15)	**Antimalarial drug discovery and development:** testing of plant extracts and evaluation of naphthylisoquinoline alkaloids *in vitro* and in animal models	TDR DFG Fonds der Chemischen Industrie Prince Leopold Institute
Ecole Nationale de Medecine et de Pharmacie (ENMP), Bamako, Mali (*n* = 14)	**Epidemiology:** seasonality and intensity of transmission, including vector studies; drug resistance **Health services research:** prophylaxis **Studies of mosquito vectors of malaria:** vector population genetics **Drug resistance studies:** epidemiology and genetics	NIAID USAID CIBA-Geigy
University of Witwatersrand, Johannesburg, South Africa (*n* = 12)	**Antimalarial drug discovery and development:** iron chelators in malaria therapy and pharmacokinetics of antimalarial drugs **Studies of malaria mosquito vectors:** mosquito genetics	South African MRC Food and Drug Administration (FDA) CIBA-Geigy
Centre National de Lutte contre le Paludisme (CNLP), Ouagadougou, Burkina-Faso (*n* = 11)	**Studies of malaria mosquito vectors:** molecular biology and genetics; characterization of mosquito behaviour	Burkina-Faso Government TDR European Commission
University of Khartoum, Sudan (*n* = 10)	**Epidemiology:** parasite population genetics and epidemiology of unstable malaria transmission **Immunology:** antibody responses to parasite antigens and links with disease symptoms **Diagnostic tests:** infection markers	TDR DANIDA Sudan Government

*See page 8 for key to abbreviations for funding organizations

were actively engaged in epidemiological studies, intervention trials or health services research. A high proportion of centres was also involved in mosquito vector studies although the overall publication output in this area was relatively low (7 per cent of total). Half of the centres published in clinical management of malaria and antimalarial drug trials, while two centres published basic studies of biochemistry, genetics and molecular biology.

Analysis of sources of funding for the top publishing institutes illustrated the substantial involvement of external funds in supporting productive research programmes. Many funding agencies focus support on specific centres. For example, French funding bodies (IRD, Institut Pasteur and the French Ministry of Cooperation) focus primarily on centres in Francophone Africa, and tend not to co-fund with organizations from other European countries or the USA. USAID and CDC tend to fund institutes concerned primarily with health services research and intervention trials, reflecting their more applied missions.

3.3.6 Impact of research

African malaria research publications have a lower mean potential impact (W = 1.67) compared with the international set of publications (W = 1.92). This is not unexpected, however, in view of the significantly more clinical nature of African malaria research compared to international research and the observation that clinical journals generate fewer citations (Dawson *et al.*, 1998). The clinical nature of African malaria research is evidenced by two types of data. Firstly, the set of African papers was published in more clinical journals, having a mean research level value (RL) of 2.24 compared with a value of 2.89 for the international set (RL1 = most clinical, RL4 = basic science). Secondly, subfield analysis showed that 81 per cent of African papers describe studies of malaria in humans, whereas the equivalent figure internationally was 46 per cent.

Table 3.5 References in national malaria guidelines and policies.

Country	Title	Total no. of references	No. of published papers*	References to in-country research	References to WHO publications	References < 5 years old
Kenya	National guidelines for diagnosis, treatment and prevention of malaria for health workers	7	0	4 (57%)	2 (29%)	6 (86%)
South Africa	Guidelines for the prophylaxis of malaria	13	6 (46%)	5 (28%)	1 (8%)	10 (77%)
South Africa	Guidelines for the treatment of malaria	25	13 (52%)	6 (24%)	6 (24%)	19 (76%)
Senegal	Programme de lutte contre le paludisme du Senegal	62	0	62 (100%)	1 (2%)	17 (27%)
Zimbabwe	National malaria control programme five year plan (1994–1998)	5	0	4 (80%)	1 (20%)	2 (40%)
Nigeria	National malaria control programme plan of action 1996–2001	5	0	4 (80%)	1 (20%)	
Tanzania	Plan of action 1997–2000 of the National Malaria Control Programme	11	0	10 (91%)	1 (9%)	11 (100%)

*Scientific papers in peer-reviewed literature

3.3.7 Malaria guidelines and policies

In order to assess the degree to which research studies influence policy and practice in malaria treatment and control, ministry of health guidelines and policies for malaria from 11 African countries were examined.

Table 3.5 summarizes the studies cited in these policies and guidelines (see Annex 5 for full titles). Only two countries, Kenya and South Africa, included a comprehensive references list in their guidelines. Senegal included specific references in the text of guidelines, but no bibliography; whereas guidelines from Nigeria, Tanzania and Zimbabwe referred to studies and research, without citing specific references. Policies from Namibia, Ghana, Zambia, Uganda and Malawi included non-specific references to in-country operational research studies and projects, mainly relating to drug resistance testing and epidemiological studies. Grey literature and local research featured prominently in the malaria guidelines examined. Of the 45 references in the Kenyan and South African malaria guidelines, only 20 (42 per cent) were publications in peer-reviewed research journals, and 15 (33 per cent) referred to local research. When Senegal, Zimbabwe, Nigeria and Tanzania are included in the analysis, 85 of the 128 references (66 per cent) cited in guidelines and policies were to research papers and studies of local origin. Fifty-one percent of the references were to papers and studies less than five years old and WHO publications constituted 10 per cent of the references in the guidelines and policies.

Despite the lack of a formal references section, the Malawi guidelines clearly refer to operational research which has affected policy. The experience of Malawi in changing from chloroquine to sulphadoxine-pyrimethamine for first line treatment of malaria has become a 'benchmark' in the development of malaria treatment policies for other countries in the region. Similarly, the references in the South African guidelines reflect the close working relationship between the South African Medical Research Council and the Ministry of Health.

The clinical or basic nature of the 45 referenced papers was characterized by analysing the distribution of the papers across different journal types. The average research level (RL) of the cited papers in the African guidelines was 1.6, with over half in level 1 (clinical) journals, indicating the strongly clinical nature of the cited papers. This is significantly lower than the mean RL for African malaria papers 1995–97 at 2.24. Similar analysis of available WHO malaria publications referenced in the guidelines revealed that the majority of cited papers were also published in clinical journals.

3.4 SUMMARY AND DISCUSSION

Bibliometric analyses were based on publications recorded in MEDLINE and SCI between 1995 and 1997. These analyses provided insight into the publications performance of African countries in malaria research in the context of worldwide productivity, based largely on international peer-reviewed journals. The use of MEDLINE in addition to SCI allowed greater coverage of clinical and field-based research, and also of non-English language journals and journals from malaria-endemic regions. It should be noted, however, that the contribution of local grey literature could not be accurately assessed, as this literature is not recorded comprehensively in any current database. To gain some insight into local research that might be influencing clinical practice in malaria-endemic countries, a complementary analysis of African malaria guidelines and policies was carried out.

Publication outputs

The number of malaria publications worldwide was small relative to other areas of biomedical research and in relation to the high global burden of disease from malaria. On average 1070 papers were produced per year between 1995 and 1997 (SCI and MEDLINE), with no marked trend in output apparent over the time period assessed. By comparison, publications relating to tuberculosis increased from 1078 in 1991 to 1521 in 1998 (MEDLINE), thus overtaking malaria research outputs.

Malaria research represented an important proportion of tropical medicine research (21 per cent of global output), but did not compete strongly with other areas of biomedical research, accounting for just 0.3 per cent of all publications recorded in SCI. By comparison, a recent review indicated that publications on arthritis and rheumatism accounted for 2.4 per cent of

world biomedical publications in 1995, and cardiology research papers constituted 10.2 per cent of the world biomedical total in 1995 (SCI database, Dawson *et al.,* 1998).

The USA followed by the UK and France were the highest contributors to global malaria publications, although the influence of the USA has decreased in recent years. African scientists and research institutes make a major contribution to the field of malaria research, participating in 17.2 per cent of the world publications output. This figure is particularly striking when compared with the very low overall African biomedical research output (1.2 per cent of world total).

Analysis of author addresses allowed identification of the highest publishing countries and institutes in Africa. Nine countries produced more than 25 publications in 1995–97, while seven research centres published more than 20 papers. The most active malaria research centres were based in East and West Africa, but very little research activity was found in Central and Southern Africa, apart from South Africa.

The distribution of active research centres across Africa may reflect differences in malaria endemicity and transmission intensity, with fewer resources being committed to malaria research in areas of lower transmission. However, investment by external funding organizations, national government commitment to science and education, and political stability are also likely to be major factors influencing levels of research activity. South Africa, Nigeria and Kenya train the highest absolute numbers of students at universities and polytechnics of all the African countries (for which data are available), and also rank in the top five for the numbers of tertiary students per 10 000 population (1991 figures, UNESCO, 1998). These figures indicate that educational base is probably an important factor contributing to the observed research strengths in these countries. Conversely, very low numbers of students from Malawi and Tanzania are trained at university level suggesting other factors are likely to be important in building successful research programmes in these countries.

Analysis of funding acknowledgements on publications clearly demonstrates the major input from external funders in supporting research at the top publishing research centres. Many funders focus their support on specific centres over a long time period: for example the UK Medical Research Council has supported the MRC Laboratories in The Gambia for over 50 years, the Wellcome Trust supports programmes in collaboration with KEMRI in Nairobi and Kilifi, IRD supports institutes in Senegal and Cameroon, and the Swiss Tropical Institute has provided long-term support for the National Institute for Medical Research in Ifakara, Tanzania. This sustained funding from external sources undoubtedly has an important impact on the productivity of research programmes, but country-specific factors such as existing commitment to research and political stability are important criteria in the selection of sites for investment of resources.

Collaboration patterns

African malaria publications have a very high level of international co-authorship. Links with researchers in Europe are most common, while collaborations between African countries are rare. Collaborations tend to be polarized between specific countries: for example there is little overlap in the African countries collaborating with the UK and with France. The low co-authorship across Africa is likely to be a reflection of poor communication links, language barriers and a lack of funding mechanisms to support trans-African collaborations.

International scientific partnerships between African researchers and colleagues internationally play an important role in maximizing the productivity of global research and building research expertise in Africa. Tropical medicine research in general exhibits a high level of international collaboration, probably reflecting the need for strong links between basic research in 'Northern' laboratories and applied clinical and field studies in disease-endemic countries. Nevertheless, the particularly extensive international co-authorship observed for African malaria research publications also reflects a dependence on external funding sources and substantial involvement of external scientists in designing and executing research programmes in some African institutes.

The present study did not attempt to assess systematically the relative contributions of African nationals and expatriate scientists to African publication outputs, for example through counting the proportion of papers with African

first authors. However, superficial inspection of author names confirmed that many African addresses were associated with expatriate scientists. A recent study found that 28 per cent of the resident scientists working on malaria in Kenya in 1998 were non-African nationals (Snow *et al.,* 1998), while in the present study 15 per cent of scientists surveyed in malaria research laboratories across Africa were non-African (Chapter 4). The proportion of expatriate scientists, however, varies considerably in different countries and institutes, and again this was evident from inspection of author names on publications from a variety of institutes. Nigeria and South Africa, particularly the Universities of Ibadan and Witwatersrand, were notable in producing a large proportion of papers that did not involve any external collaborations or input from expatriate scientists. This high degree of self-reliance is likely to be linked in part to the fact that South Africa and Nigeria not only have the highest number of students trained to tertiary level, but over 98 per cent of these are trained at home. By comparison, Tanzania, Kenya and Cameroon respectively train 42, 20 and 25 per cent of tertiary students overseas (1985–92 figures, UNESCO, 1998). Enforced isolation during apartheid is likely to be another contribtory factor to South Africa's lower collaboration rate.

Funding sources

Analysis of funding acknowledgements on publications revealed that a broad range of organizations support malaria research, with some being more prominent in the international set of papers and others featuring more strongly in the African papers. The results were able to indicate important contributors to malaria research funding, although they could not provide an accurate measure of the magnitude of financial support.

TDR followed by the Wellcome Trust were the two organizations most commonly cited as sources of funding for both the international and African sets of papers. The percentage share of TDR has, however, decreased since an earlier survey of 1984, 1989 and 1994 papers, while the shares of the Wellcome Trust and the European Commission have both increased. Some African government agencies featured in the funding of malaria research, most notably the Kenyan Medical Research Institute. Only two commercial companies were identified as supporting malaria research in Africa.

Research subfields

Subfield analysis demonstrated that research in Africa focuses primarily on clinical and field studies with practical applications in Africa. Outputs from basic science studies of the malarial parasite were very low. Examination of the publications of individual institutes across Africa provided an important insight into the research specializations of these centres. The results, however, reflect research carried out prior to 1997 and as such are not necessarily an accurate view of current studies.

Impact of malaria research

African publications had a lower potential citation impact than the international set of papers. However, standard citation indices are measures of the impact of research on the scientific community and they are positively correlated with research that is more basic in nature. African malaria research is therefore intrinsically disadvantaged in this type of assessment due to its highly clinical character. Alternative approaches are required to assess the impact of medical research, particularly more applied and clinical research, on health policy and practice, or on population health status.

The current study examined national malaria guidelines and policies for the treatment and control of malaria from a sample of African countries to assess links between scientific research and policies. The usefulness of this approach was, however, limited by the lack of a systematic approach to citing scientific literature in the documents examined. Nevertheless, some tentative conclusions can be drawn on the basis of the limited information obtained. Firstly, just over half of the references in guidelines were to studies less than five years old, indicating that policies are being informed by recent research. Furthermore, in-country research, often recorded in grey literature, was most frequently referred to, and references to international studies in peer-reviewed journals were less prominent. The influence of local research on health policies was also observed in a study of 15 British clinical guidelines, where 33 per cent of the cited papers were published by UK authors, over three times the British share of international biomedicine publications (Grant, 1999). However, 96 per cent of papers cited in bibliographies in the UK clinical guidelines were

from research journals, contrasting with the situation in Africa where references to grey literature were more common. The studies referenced in African guidelines tended to be clinical in nature, with few references to basic science, and this was also the case for the UK clinical guidelines. WHO documents constituted 10 per cent of the references in African guidelines and policies, indicating the importance of WHO as a source of high-quality and readily available technical material.

The observed significant role of local and clinical research in determining health policy formulation in Africa and elsewhere is an argument that might favour investment in the local research base in individual countries, and maintenance of strong clinical science research in order to achieve a direct impact on health.

The development of health policies and guidelines is a complex process requiring the involvement of many different individuals and organizations. A range of factors will therefore influence the choice of information sources used in policy formulation. The observed dependence on local and grey literature in Africa may in part reflect the lack of availability of international scientific literature to policy makers. However, a more significant factor may be the importance assigned to locally relevant studies, and perhaps the difficulty in publishing this type of research in international journals. A substantial amount of scientific material is contained in local conference and meeting reports, non-governmental organization (NGO) survey material and ministry of health reports which are not recorded in any major databases, and are therefore not easily accessible to the worldwide scientific community. These sources are often not subject to peer review, but nevertheless comprise a significant body of knowledge, which is likely to be important in the development of local policies.

The infrequent use of peer-reviewed literature in policy formulation in African health guidelines may also reflect a lack of a strong research culture in the circles responsible for policy development, and a broader need for more open dialogue between research and control communities. Early involvement of ministries of health in research programmes can inform research design and objectives, and is more likely to lead to prompt and efficient incorporation of results into policy. Greater access of ministries of health to internationally published research results would facilitate the process by which research results influence practice. The use of non-peer-reviewed literature in policy formulation raises potential concerns regarding the lack of a mechanism to assure the quality of the research results.

With the limited availability of resources for support of scientific research activities there is an increasing need to measure the productivity of scientists and the impact of their research. Standard bibliometric citation techniques are more suited to measuring the impact of basic research in advancing scientific knowledge and are less appropriate for assessment of the impact of more clinical and applied research. Despite this, there is a dependence of funding organizations on high-profile publications for evaluating research productivity in all fields. This approach will tend to favour basic scientists in competition for funds and potentially discourage researchers from working in more applied research areas, even though these areas are essential to achieve an ultimate impact on health. Alternative methodologies are therefore required that can provide a rational basis for investment in research that has the potential to influence evidence-based medicine and approaches to disease control.

Assessment of the degree of incorporation of scientific research into national health policies and guidelines could potentially provide an effective and important method of evaluating research impact on healthcare and disease control practices. However, the format of national guidelines must include detailed bibliographies for accurate analysis of the information guiding policies.

Malaria research capacity in Africa

4

In the previous chapter, analysis of publications outputs provided a powerful and relatively straightforward method to characterize a range of different aspects of malaria research activity in Africa. This approach, however, is necessarily retrospective as it generally reflects research carried out in the few years prior to the publication date. It also cannot provide more detailed insight into the human resources and infrastructure in African research centres. This chapter therefore takes an alternative approach, a questionnaire-based survey, to obtain information directly from malaria research groups currently active in Africa. The survey gathered information on ongoing and past research projects, the expertise and training paths of African malaria researchers, field and laboratory facilities and sources of funding. It also provided an opportunity for African scientists to express their opinions and experiences on difficulties in pursuing a career in science and on potential solutions to building sustainable research activity in Africa. The bibliometric analysis and the survey of research centres are complementary approaches, which together provide a detailed picture of the current status of malaria research capacity in Africa.

4.1 METHODS

A questionnaire was designed for the MIM survey concerning research capacity in African malaria research centres. In developing the questionnaire, two pre-existing sources of information were taken into account:

- the 1997 Directory of the African Malaria Vaccine Testing Network (AMVTN),[1] which presents information on 30 malaria research institutions from 20 African countries;
- the 'Inventory of Resources and Activities', produced for the International Conference on Malaria in Africa, held in Dakar, Senegal, 1997,[2] which presents summary information on 41 research groups in Africa.

The MIM survey aimed to build upon and extend these two reports, rather than to duplicate them. Some elements of the AMVTN Directory were incorporated into the MIM survey to increase coverage of data. In addition, some analyses were not restricted to MIM survey results, but were based on data from the two pre-existing reports.

The questionnaire comprised two sections (Annex 8). The director of the research programme was asked to complete section A of the questionnaire, and to distribute section B to all members of staff educated to at least first-degree level.

Section A requested summary information on the research group:

- the number of researchers in the group;
- the proportion of time spent on malaria research;
- the research expertise within the group, including the number and qualifications of individuals trained in different disciplines;
- the research grants held by the group during 1993–98.

Section B sought information on the career paths of individual researchers and the opinions of these researchers on effective approaches to develop research capacity in Africa. Details were requested from researchers on:

- current employment position, including sources of support for salary and research;
- all scientific training undertaken, including location and source of funding;
- difficulties experienced during their research careers and potential solutions to identified difficulties;
- optimal mechanisms to build research capacity.

Malaria research laboratories in Africa were identified from the AMVTN and Dakar directories, analysis of malaria publications (Chapter 3), and lists of African delegates at recent malaria conferences. Questionnaires were sent by post, fax and e-mail, depending on the available modes of communication, to 52 senior scientists leading malaria research programmes at 45 institutions in Africa. Questionnaires were sent in English or French according to the predominant language of the research programme.

[1] www.amvtn.org

[2] www.niaid.nih.gov/dmid/malafr/default.htm

4.2 RESULTS

The results presented in this chapter are derived from the data collected during the MIM survey, with three exceptions. The analysis of research expertise used data collected from the MIM survey combined with data from the AMVTN directory; the analysis of laboratory facilities was based on data from the AMVTN and Dakar directories; while the analysis of the epidemiological conditions at field research sites used data from the AMVTN Directory.

Contact details for malaria research groups are shown in Annex 12.

4.2.1 Overview of research groups

Survey respondents

More than three-quarters of the research programme leaders contacted participated in the MIM survey. The respondents comprised 48 research groups based at 40 institutes in 19 African countries, mainly in East and West Africa (Figure 4.1, Annex 9). Information on additional groups was obtained from the AMVTN Directory, such that the total data set included 54 groups in 22 countries.

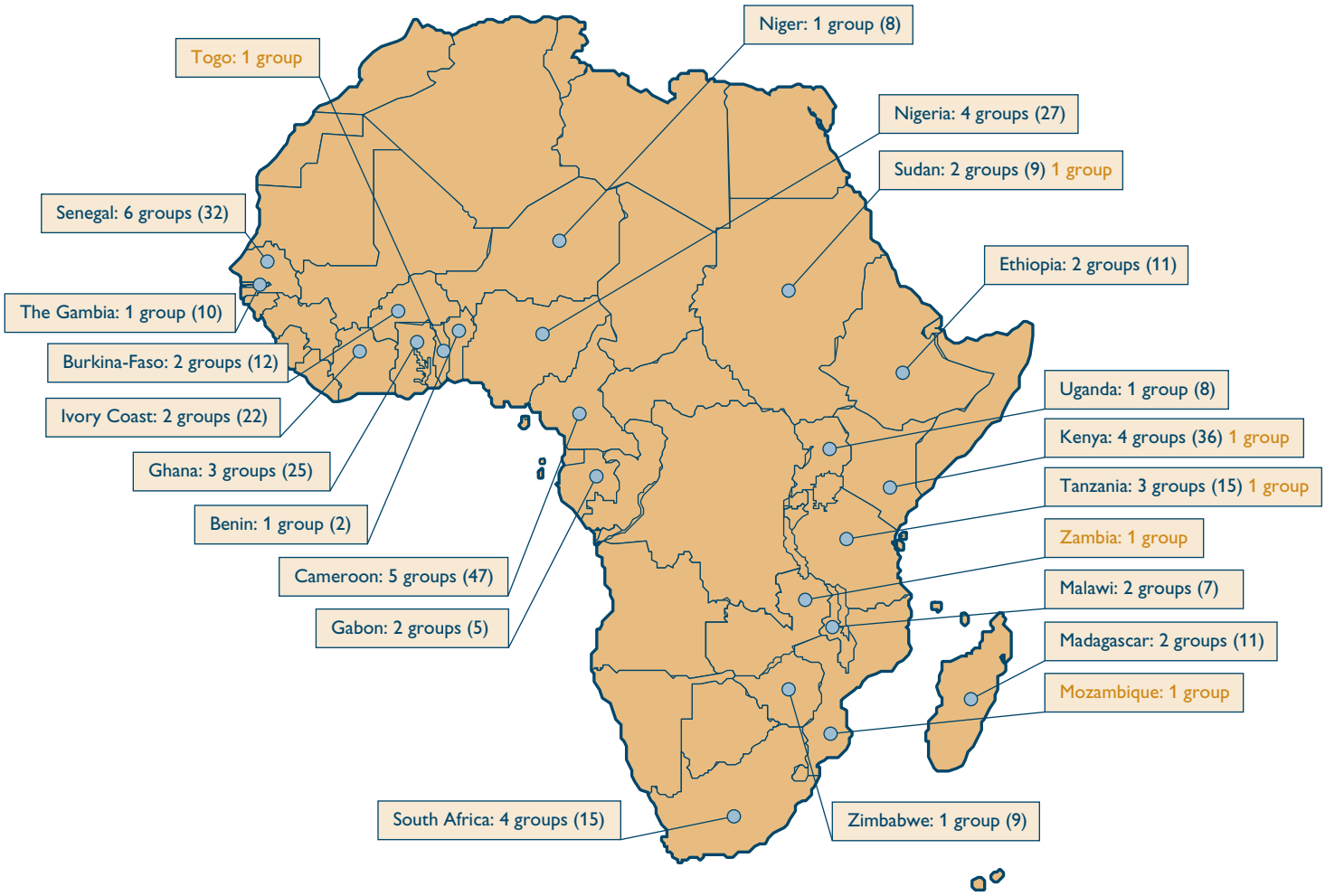
The sample group included 13 of the 18 top publishing African malaria research centres identified from the bibliometric analysis (Chapter 3). It should be noted that the concept of a 'research group' or 'centre' was difficult to define due to the widely varying situations in different research institutes and the added complication of collaborations or formalized links between institutes (e.g. a university and the Ministry of Health). Interpretation of results was standardized as far as possible, but some variation is inevitable. In general, the returned questionnaires were completed in full by researchers, although there were some gaps and omissions.

The questionnaire responses confirmed that malaria was the major topic of investigation: 34 of the 48 groups devoted more than 50 per cent of their time to malaria research.

Laboratory facilities

A summary of the equipment and facilities in African laboratories was produced using data from the AMVTN and Dakar directories. This analysis provides an overview of the facilities present in African research institutions at the time of survey (1996–97), although it cannot indicate the quality or functionality of equipment. Owing to variation in the response rates to individual questions, the sample size for this analysis ranged from 35 to 39 research groups and institutes. All research institutions that responded had access to telephone, fax and computing facilities, with 91 per cent reporting e-mail connections. Core laboratory facilities (freezers, centrifuges, incubators and microscopes) were present in over 90 per cent of research laboratories, and around 80 per cent were equipped with ELISA readers and laminar flow hoods. More specialized facilities such as gel electrophoresis equipment and PCR machines were present in 76 per cent and 58 per cent of laboratories respectively. All laboratories that responded had at least one four-wheel drive vehicle for field work.

Figure 4.1 Malaria research groups participating in the MIM survey or included in the AMVTN directory.
Groups from the AMVTN directory are shown in brown
(*n*) = Number of responding scientists per country



Additional data on six research groups from the AMVTN directory (shown in brown) were included in the analysis of research expertise (Annex 9). Two questionnaires were completed by African researchers working overseas.

Table 4.1 Malaria epidemiology at African research sites (summarized from AMVTN Directory).

Country	Institution	Seasonality (1–4 year age group)	% Prevalence	*Anopheles* vectors	Infective bites per person per year
Benin	Regional Center for Entomological Research of Cotonou	12/12	67	*gambiae* s.s. *melas*	51–100
Burkina-Faso	Centre National de Lutte contre le Paludisme, Ouagadougou	12/12	92	*gambiae* s.l. *funestus*	101–300
Burkina-Faso	Centre MURAZ, Bobo Dioulasso	12/12		*gambiae* s.l. *funestus*	>300
Cameroon	L'Organisation de Coordination pour la Lutte contre des Endémies en Afrique Centrale (OCEAC), Yaoundé	12/12	90	*gambiae* s.l. *funestus*	51–300
Ivory Coast	Pierre Richet Institute, Bouaké	>6/12	10	*gambiae* s.l. *funestus*	
Ethiopia	Jimma Institute of Health Sciences	>6/12	6	*gambiae* s.l.	
Gabon	Centre International de Recherches Medicales de Franceville	12/12		*gambiae* s.l. *funestus*	51–100
The Gambia	UK MRC laboratories: Basse field station	>3–6/12	30	*gambiae* s.l.	
The Gambia	UK MRC laboratories: Fajara	>3–6/12	34	*gambiae* s.l.	<1
Ghana	Navrongo Health Research Centre	12/12	85	*gambiae* s.l. *funestus*	>300
Ghana	Noguchi Memorial Institute for Medical Research, Legon	12/12	50	*gambiae* s.l. *pharoensis* *melas*	
Kenya	Division of Vector Borne Diseases, Nairobi	12/12 >6/12 3–6/12			
Kenya	KEMRI–Wellcome Trust Collaborative Programme, Kilifi	12/12	47	*gambiae* s.l. *funestus*	21–50 (2 district zones) 51–100
Kenya	Vector Biology and Control Research Centre Kisumu	12/12	90	*gambiae* s.s. *arabiensis* *funestus*	
Mozambique	Instituto Nacional de Saude, Maputo	12/12	70	*gambiae* s.l. *funestus*	6–20
Niger	Research Center for Meningitis and Schistosomiasis, Niamey	12/12	74	*gambiae* s.l.	
Nigeria	Cellular Parasitology Programme, University of Ibadan	6/12			>300
Senegal	Institut de Recherche pour le Développement-Dakar	<3/12	90	*gambiae* s.s. *arabiensis*	6–20
Senegal	Institut Pasteur de Dakar	12/12	95	*gambiae*, *funestus*	101–300
South Africa	National Malaria Research Programme, Medical Research Council, Durban			*arabiensis*	<1 (due to low incidence)
Sudan	Faculty of Medicine, University of Khartoum	3–6/12	16	*arabiensis*	<1
Sudan	Blue Nile Research and Training Institute	<3/12		*arabiensis*	
Tanzania	Amani Medical Research Centre	12/12	90	*gambiae* s.s. *funestus*	>300
Tanzania	Ifakara Health Research and Development Centre	12/12	92	*gambiae* s.l. *funestus*	>300
Tanzania	Institute of Public Health, Dar es Salaam	12/12	80	*gambiae* s.s. *gambiae* s.l. *funestus*	>300
Togo	National Malaria Control Programme (MOH), Lomé	12/12		*gambiae* s.l. *melas* *funestus*	
Uganda	Med Biotech Laboratories, Kampala	12/12	85	*gambiae* s.l. *funestus*	
Zambia	Tropical Diseases Research Centre, Ndola	12/12	78	*gambiae* s.l. *funestus*	
Zimbabwe	Blair Research Institute, Harare	12/12	10	*gambiae* s.s. *arabiensis* *funestus*	

Malaria epidemiology characteristics

Data from the AMVTN Directory were analysed to characterize malaria epidemiology at different field research sites. The results are summarized in Table 4.1. Data were available for 29 centres (which covered 14 of the top 18 publishing centres identified in Chapter 3), and encompassed 32 different field study areas. The sites cover a broad spectrum of malaria endemicities and vector systems. *Plasmodium falciparum* is the principal human parasite at all sites although varying levels of other parasites were also reported. For example, *P. vivax* is prominent in Ethiopia.

Research funding

Research funding was investigated by analysis of two types of data collected from the questionnaire: research grants held by programme directors during 1993–98 (Section A), and funding acknowledgements for current research support listed by individual respondents (Section B). Summaries of both sets of data are presented in Table 4.2. The data provide an indication of the level of support from different funding organizations for malaria research in Africa, although several points should be noted:

- The analysis of research grants does not provide information on the magnitude of the various awards, which may vary considerably. For example, a single grant to provide major support for a research institute would not be adequately represented when compared to a large number of smaller awards to a variety of institutes.
- Although the coverage of laboratories across Africa was generally high, gaps in data may have led to under-representation of some funding organizations, particularly if funds are directed to a specific centre that did not participate in the survey.

A total of 284 grants were reported by the directors of 46 research groups in the responses to Section A of the questionnaire, and 225 researchers (African and non-African) provided details of their research funding in Section B. The research topics listed on awards were consistent with the malaria publications output from Africa (Chapter 3), with the majority of grants supporting studies in clinical medicine, epidemiology, intervention trials and health services research. Sixteen per cent of awards supported research on subjects other than malaria.

The sources of support for African malaria research were many and diverse (Table 4.2, Annex 10). The majority of research funding came from organizations based outside Africa, particularly from European sources, with only 9 per cent of research grants and 21 per cent of individual funding acknowledgements listing an African governmental or other local source. Nevertheless, local funding was still the most frequently acknowledged single category of support for individual researchers. In terms of research grants, TDR emerged as the most frequently acknowledged funder, accounting for 20 per cent of all grants. A third of awards overall were from a WHO programme. Commercial companies made a relatively low, but significant combined contribution, accounting for 6 per cent of research grants. Although the numbers of grants and funding acknowledgements cannot give an accurate measure of the relative levels of investment by different organizations, the results clearly identify those organizations making major contributions towards supporting the malaria research base in Africa.

Table 4.2 Sources of funding for African malaria research laboratories.

Funder	Research grants held by African laboratories (1993–98)	Funding acknowledgements for current research from individual respondents
UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR)*	61	80
French Ministry of Cooperation	33	26
World Health Organization (WHO)*	25	31
Local sources†	24	94
Wellcome Trust	20	20
European Commission	17	25
Pharmaceutical companies/ industrial sources	16	13
Agence universitaire de la Francophonie (AUPELF–UREF)	9	8
Institut Pasteur	8	15
Danish International Development Agency (DANIDA)	7	14
International Development Research Center, Canada	6	6
UK Department for International Development	5	4
US National Institutes of Health§	5	17
Institut de Recherche pour le Développement (IRD)	1	22
Others	47	78
Total	**284**	**453**

*Research grants specifically acknowledging the UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR) were analysed separately from other acknowledgements to the World Health Organization (WHO)

† Awards from governments of developing countries and other local sources were classified together under the heading 'Local sources'

§ Awards from the various institutes of the US National Institutes of Health were pooled for analysis

Research collaborations

Information on the research links of African laboratories was obtained by analysis of stated collaborations on research grants. One-third of awards involved a research collaboration, with European countries being the most frequent collaborators (Table 4.3). Collaborations across Africa accounted for 16 per cent of the total.

Research expertise

Overview data of research groups completed in Section A of the MIM questionnaire were analysed together with AMVTN data to assess the number of individuals trained to different degree levels in particular disciplines (Figure 4.2). In total, 752 individuals qualified to at least first-degree level were identified as being actively involved in research programmes in the groups surveyed (AMVTN and MIM survey):

Table 4.3 Regional breakdown of stated collaborations on research grants.

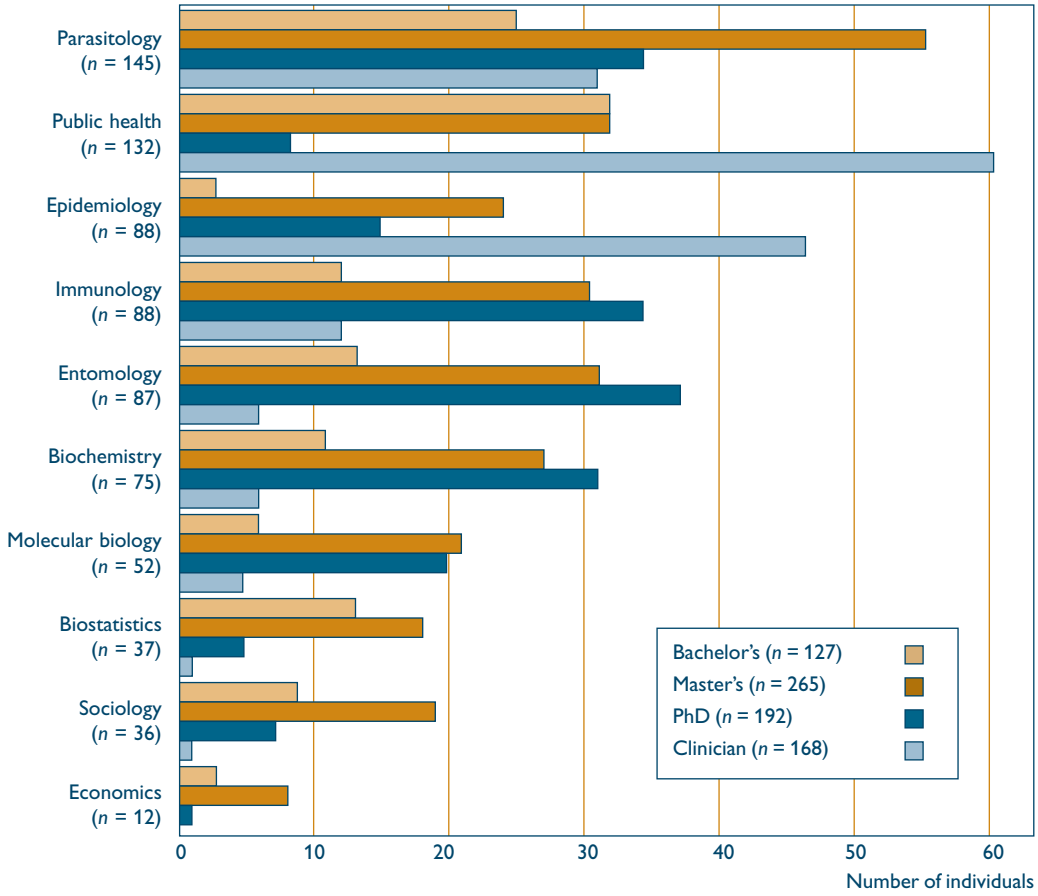
Geographical region	Number of collaborations on research awards
Europe	81
Same African country	39
Other African country	25
USA	11
Asia	1

Number of awards that listed collaborations = 99 Total number of collaborations listed = 157

26 per cent to PhD level, 35 per cent to Master's level and 17 per cent to Bachelor's degree level. Clinically qualified individuals accounted for 22 per cent of the total. Full differentiation of African and non-African scientists was not possible, but available data showed that there was substantial representation of expatriate scientists in some centres, while others were entirely composed of African nationals. About a third of research groups were led by overseas scientists.

The majority of research groups appeared to be multidisciplinary, with expertise in a range of different research skills. The broad research areas of parasitology and public health were most strongly represented, with more than 130 trained personnel in each category. The disciplines of epidemiology, immunology, entomology and biochemistry also showed relatively high levels of overall expertise. In contrast, few individuals reported training in biostatistics, sociology and

Figure 4.2 Research expertise in African malaria research laboratories and institutions.



Number of individuals per discipline identified from the MIM survey and AMVTN Directory. Total number of individuals identified = 752.

economics. Postdoctoral scientists were most numerous in parasitology, immunology, entomology and biochemistry, with each category having 30–40 researchers trained to PhD level. More than 50 scientists with expertise in molecular biology were also identified, a high proportion of these at postdoctoral level. Master's qualifications predominated in parasitology, whereas clinically qualified researchers were most common in public health and epidemiology.

4.2.2 Profile of malaria researchers

Research qualifications

A total of 313 scientists, of whom 85 per cent were African nationals, completed individual Section B questionnaires. This number is less than half the number of researchers reported by group leaders to be engaged in research in the centres surveyed (see Figure 4.2). Hence, the coverage in this survey was not comprehensive. In certain cases, individuals were unable to complete questionnaires as they were undergoing training outside their home institute. Nevertheless the data provide some important insights into existing research capability and the training paths of scientists in African research centres.

Researchers at all stages of career progression were represented in the sample of respondents, with postdoctoral researchers and PhD students constituting the largest group of African researchers: 37 per cent in total (Table 4.4). A large proportion of respondents held more than one higher degree for example 84 per cent of postdoctoral researchers also held a Master's degree, and 44 per cent of clinicians held additional PhD, MD or Master's qualifications.

Current position

Sixty-four per cent of African survey respondents held a permanent position of employment. Researchers employed on temporary contracts were predominantly junior scientists. Salary provision was mainly from within Africa: 68 per cent of African researchers received a salary from the national government or other local source. Salary provision from external sources tended to come from organizations providing substantial support to specific research centres in Africa, namely Institut de Recherche pour le Développement (IRD), the Wellcome Trust, Institut Pasteur, the US Centers for Disease Control and the UK Medical Research Council (Figure 4.3).

Training paths of African researchers

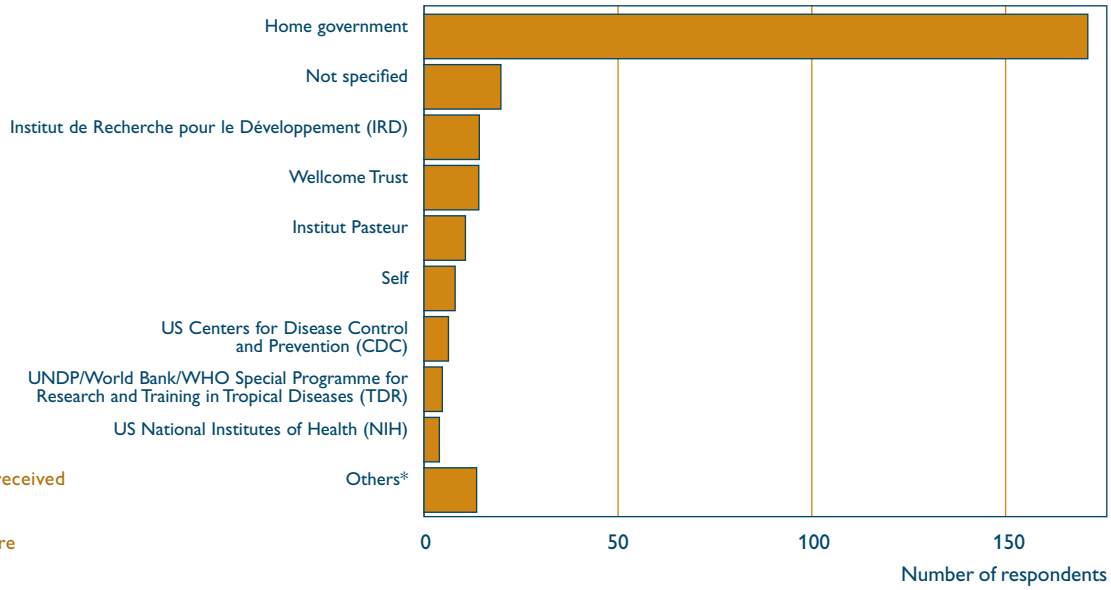
The majority of African scientists (90 per cent) completed their Bachelor's degree in Africa, with 52 per cent funded by national governments, 29 per cent self-financed and 3 per cent funded by an organization based outside Africa. Many more researchers (54 per cent in total) completed postgraduate training outside their home country (Figure 4.4): 28 per cent in Europe, 11

Table 4.4 Survey respondents according to nationality and highest qualification obtained.

Research level	Number of respondents (% of total for each group)			
	African		non-African	
Bachelor's	42	(16%)	2	(4%)
Master's students	12	(5%)	0	
Master's	50	(19%)	4	(9%)
PhD student	24	(9%)	2	(4%)
Postdoctoral	74	(28%)	16	(34%)
Clinician*	59	(22%)	23	(49%)
Diploma/certificate	2	(1%)	0	
Total	**263**	**(100%)**	**47**	**(100%)**

*Clinicians with higher degrees (44 per cent of total) are included in this category
Three additional African respondents could not be classified due to incomplete information

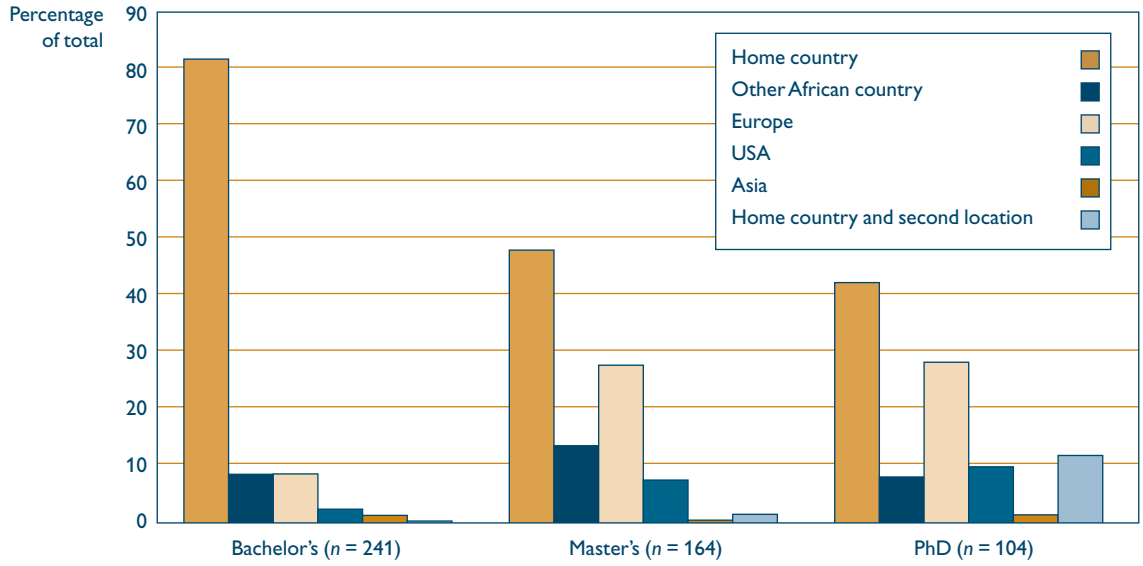
Figure 4.3 Salary/stipend provider for African researchers (*n* = 278).



*Organizations that received fewer than five acknowledgements are classified as 'Others'.

per cent in another African country, 10 per cent in the USA or Asia, and 5 per cent in a combination of their home country and a second location (usually Europe or the USA). However, variations in patterns of training were evident for different countries. For example, more than 80 per cent of respondents in Nigeria and South Africa conducted postgraduate training in the home country. Similarly, a high proportion of respondents in Cameroon and Senegal conducted training in Africa (in the home country or another African country). In contrast, the majority of Tanzanian respondents completed postgraduate training outside the home country, mainly in Europe or in another African country. These differences may reflect the educational facilities present in each country, and/or established links with researchers or institutes outside Africa.

Figure 4.4 Location of training for African scientists.



Funding for postgraduate training was mainly from external sources, particularly where training was conducted outside Africa: 65 per cent of funding acknowledgements were to organizations based in developed countries at PhD level and the equivalent figure at Master's level was 46 per cent. African governmental sources were still the highest single contributor to postgraduate training, accounting for 23 per cent of funding acknowledgements in total (Table 4.5). TDR was the second most frequently acknowledged funder, while IRD and the French Ministry of Cooperation were also prominent supporters of postgraduate studies in the sample analysed. However, it was evident that there were many diverse funding organizations that contributed to research capacity building in Africa (Annex 11). It was also observed that a high proportion of African scientists funded their own studies at all levels of training.

4.2.3 Training needs and solutions: an African perspective

A total of 244 researchers (African and non-African) completed the opinion survey in Section B of the questionnaire. The responses represent the personal views of a diverse group of malaria researchers in Africa on research capacity strengthening. The following section presents the questions posed to researchers and the responses received.

Please identify any specific difficulties that you may have experienced in developing and maintaining a research career in tropical medicine. How might these difficulties be overcome in the future?

Not unexpectedly, the most frequent response to this question was lack of funds. However, respondents identified the key areas that, in their opinion, required greater financial investment as follows.

Table 4.5 Sources of funding for Master's and PhD training of African malaria researchers.

Funder	PhD	Master's
Home government	23	50
UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR)	23	26
Self	15	37
Institut de Recherche pour le Développement (IRD)	10	12
Not specified	10	11
French Ministry of Cooperation	6	5
Wellcome Trust	5	3
European Commission	5	3
Danish International Development Assistance (DANIDA)*	4	1
Agence Universitaire de la Francophonie	4	0
Swedish International Development Assistance (Sida/SAREC)	4	0
US National Institutes of Health	3	2
Others	25	31
Total number of acknowledgements	**134**	**180**

* Includes acknowledgements to the Danish Bilharziasis Laboratory

Research funding

Thirty-six per cent of respondents indicated that they experienced difficulties in obtaining research grants due to limited funding opportunities, intense competition, and lack of awareness about potential sources of funding. Overall, respondents wanted a general increase in research funding from both local and international sources, particularly schemes to enable junior researchers to develop their careers in Africa. Training in grant application writing to enhance the competitiveness of African researchers; reservation of a quota of awards for junior researchers (without compromising standards); and efforts to increase awareness among the research community about potential funding sources were proposed as solutions to this problem.

Laboratory facilities

Poor laboratory facilities, together with the high cost of reagents and lack of efficient systems for obtaining reagents were cited as problems by 26 per cent of respondents. The general view held was that long-term and large-scale investment by national governments and international funding organizations is needed to improve infrastructure, as the short-term nature of science funding fails to address this problem. Respondents also suggested provision within research grants for equipment, and the creation of funding schemes to support upgrading of facilities. Establishment of distribution networks in Africa for laboratory reagents, equipment spares and repair facilities was proposed by respondents as a practical solution to counteract the costs and delays associated with the purchase of reagents and maintenance of laboratory equipment.

Communications

Poor telecommunications, computing and library facilities were viewed as an obstacle to the development of viable research partnerships within Africa and internationally by 18 per cent of respondents. Respondents proposed long-term commitment and concerted action by governments and international funding agencies to improve telecommunications. To address the immediate problem, respondents proposed strengthening of existing facilities in order to establish a network of laboratories, to which satellite groups might link up in future. It was recognized that the increasing availability of journals over the Internet might circumvent the need for a well-stocked library, but would in turn require improvements in computing and telecommunication facilities. Respondents also suggested the introduction of a reduced journal subscription rate for developing countries.

Salary provision and career development

Poor salary and limited career development opportunities were cited as difficulties by 17 per cent of respondents, who considered that these factors contributed to the exodus of researchers from Africa. Respondents recommended that national governments increase salaries and take action to standardize pay and working conditions to enable researchers to focus full-time on research. Respondents observed that a lack of local employment opportunities deters junior researchers from pursuing their career in Africa following completion of training abroad and that researchers without a local position are usually ineligible to apply for international sources of research funds. To overcome this difficulty, respondents proposed that African institutes create honorary positions for researchers and that research grants from international organizations should include full salary costs, or at least a supplement to the local salary.

Respondents also highlighted the difficulties encountered by senior researchers, such as an inability to keep up to date with scientific advances due to lack of on going training; inexperience in running a research programme, particularly managing staff and budgets; lack of technical support; and scientific isolation in Africa. To tackle these problems, respondents recommended provision within research grants for training attachments; management and financial training; funds to support technical staff; and funds to attend meetings and conferences.

Other difficulties (< 10 per cent of respondents)

In addition to the main issues outlined above, a number of other difficulties were identified in the questionnaire responses.

- **Poor participation by the local population in studies and trials.** Respondents felt that action should be taken by governments and researchers to raise public awareness about research and its potential benefits to the community.

- **Lack of government cooperation and support for research.** Respondents reported a general lack of government support, and highlighted the failure of governments to make use of research findings, and government bureaucracy that hinders the process of obtaining travel visas and the transport of research materials as particular problems. Respondents recommended greater dialogue between scientists and government officials.
- **Inadequate resources for conducting field trials.** Investigators conducting field studies in remote areas reported problems due to poor road conditions and a lack of suitable vehicles. Respondents proposed that research awards should include provision for purchase of vehicles and maintenance costs, where necessary.
- **Lack of trained technical support staff.** This problem was deemed to put a considerable burden on the principal investigator, who has to contend with the demands of a research career, teaching or hospital commitments, and all the other activities connected with running a laboratory. It was also observed that training of junior and technical staff would boost staff morale.
- **Funds to attend meetings and conferences.** Researchers reported difficulties in obtaining funds to attend meetings and conferences. They recommended provision within research grants for travel to meetings and conferences to enable researchers to present results and establish contacts and collaborations, as well as the establishment of networks of researchers locally and internationally to ensure that scientists have opportunities to discuss research findings.
- **French–English language barrier.** Researchers from French-speaking African countries cited the French–English language barrier as a difficulty in communicating research results and establishing collaborations.

What types of schemes (e.g. collaborative, training, funding etc.) do you consider, are or would be, particularly beneficial in developing research capacity in African universities, research institutions and ministries of health? Please give details of level of training (MSc, PhD etc.), mechanism, location etc.

Training

The overall availability of training opportunities and financial support for training was of concern to most respondents, and 77 per cent of respondents highlighted a need for additional opportunities at Master's and PhD level. Respondents identified the following as elements of a successful training scheme:

- training as a component of a local research project to ensure relevance to the particular health problems of a country;
- exposure of students to the high-quality research environment in external centres of excellence;
- application in Africa of techniques learnt abroad to ensure technology transfer.

In general, respondents considered that all available mechanisms for training should be utilized, whether in Africa or in developed countries, although there was some variation in the preferred location of training. For example, proponents of local training considered that training abroad was ineffective as researchers may not return home following training; "techniques learnt abroad fail to be applied in Africa due to differences in the conditions of the different environments (i.e. laboratories)"; and the costs of training abroad are prohibitively expensive. Furthermore, respondents observed that opportunities for training in Africa are under-utilized due to lack of funds, as international funding organizations tend to support training in developed countries. Respondents proposed greater investment in developing African centres of excellence as this would contribute to building sustainable research capacity and enable the majority of training to be conducted in Africa. Nevertheless, many respondents recognized the importance of training links with developed countries in building research expertise in Africa. The 'sandwich' format of training was considered a useful mechanism to allow "students from Africa to undertake training in developed countries and then return home to do their

project work. In this way they would obtain expertise from abroad and be able to use it to solve problems on the ground."

Although postgraduate training was identified as a priority, all stages in the career development of scientists were considered to require additional attention. The career development of postdoctoral scientists was considered important by respondents, who proposed provision within research grants for training attachments, and regular training workshops on specialist skills and topics to keep researchers up to date with scientific advances. Respondents also felt that "training at junior and technical levels would improve and motivate staff and help to create the next scientific generation". Similarly, inclusion of a stronger research component in undergraduate degrees would encourage a 'research culture' in developing countries and contribute to research capacity strengthening.

Collaborations

Collaborations within Africa and with colleagues internationally were cited by 55 per cent of respondents as an important means of strengthening research capacity in Africa. Respondents envisaged the principal benefits of collaborations to be:

- opportunities for training;
- coordination of research activities and the ability to participate in multidisciplinary research projects conducted at different sites;
- sharing of knowledge and experiences, resulting in technology transfer between research institutions.

The value of training provided by visiting overseas scientists was also recognized. Furthermore, respondents wanted greater research cooperation within Africa, citing the TDR Multilateral Initiative on Malaria (MIM) awards scheme as a model that should be extended to enable the development of research collaborations and networks in Africa.

The need to promote greater interactions between researchers and ministries of health was raised by respondents.

4.3 SUMMARY AND DISCUSSION

The present study used a questionnaire-based approach to gather data on the current human and infrastructural resources in African malaria research laboratories. Detailed information was obtained on the career paths of African researchers and on sources of funding for research and training. The opinions of African researchers on difficulties experienced and potential routes to building effective research capacity in Africa were also obtained. Overall, the response rate to the survey was high (>80 per cent), particularly in view of the communication difficulties usually associated with Africa. Researchers in 19 countries, the majority based in East and West Africa, took part in the survey and the distribution of questionnaires in English and French was successful in ensuring participation from researchers in both Anglophone and Francophone Africa. However, five of the 18 highest publishing research centres (see Chapter 3) did not respond to the survey, thus illustrating the difficulty in obtaining complete coverage using a survey approach. Data from the MIM survey were supplemented with information from the AMVTN Directory such that the total data set encompassed 54 groups in 22 countries across Africa.

There is a lack of reliable national data on personnel in science and technology, and hence of meaningful regional figures for human resources in sub-Saharan Africa. Available information suggests that the numbers of trained African scientists are low. Figures from the Observatoire des Sciences et Techniques (Paris) (UNESCO, 1996) indicate that there are in the region of 0.4 scientists per 1000 population in Africa, compared with 1.8 and 2.7 for the European Union and the USA respectively. However, other data suggest a very much greater disparity in human resources for scientific research between Africa and the established market economies. The current MIM survey has gathered important data on the training and expertise of African scientists engaged in one focused area of biomedical research: malaria research. It should be noted, however, that this field probably represents one of the strongest areas of biomedical research in Africa: 21 per cent of global 'tropical medicine' publications

are devoted to malaria research and 17.2 per cent of these malaria publications involve African scientists (Chapter 3).

Research expertise: qualifications

Overall, the survey results are encouraging as they indicate that a core of trained African malaria researchers has been established. Data from 54 research groups identified 752 researchers engaged in malaria research who were trained to at least first-degree level. A large proportion of these researchers had higher qualifications: personnel trained to Master's level were most numerous, although postdoctoral and clinical scientists were also well represented. Nearly half of clinical scientists held higher degrees. There is a culture within Africa to progress through Master's training before proceeding to a PhD and the majority of postdoctoral researchers held Master's degrees.

However, the 192 postdoctoral scientists and 165 clinical scientists identified were dispersed across 22 African countries so that the numbers per country are generally small. In addition, many of the most productive research centres involved substantial input from senior expatriate scientists. The results therefore indicate a strong need for additional African scientific leaders who are able to conduct innovative and independent research.

To put the numbers of trained malaria researchers into context requires comparison with figures for the numbers of scientists engaged in health research in Africa. Data in this respect are limited and subject to inaccuracies and incompleteness. Figures for 1995 estimate that researchers in national research centres in 38 African countries totalled 13 174, with a quarter of these centres focusing on health and nutrition, basic sciences or social and human sciences (Gerring, 1995). These figures do not encompass all research institutes or countries, but they nevertheless support bibliometrics data indicating that malaria research is a strong component of African biomedical research. Hence, it is likely that the trained malaria scientists identified in this survey represent one of the strongest sets of health researchers in Africa. Expertise in most other diseases prevalent in Africa will almost certainly be considerably less.

Research expertise: scientific disciplines

The ongoing research programmes reported by African research groups in the current survey largely reflected the research strengths identified by analysis of malaria publications (Chapter 3), with a focus on clinical and field studies. This more applied focus was also reflected in the specializations of trained personnel in the sample group. However, expertise in the more basic science categories also showed a notable presence. In view of the low publication outputs from Africa in basic studies of *Plasmodium* (1995–97, Chapter 3), the present results suggest that African researchers are increasingly training in basic laboratory disciplines. The majority of research centres incorporated expertise in multiple research disciplines, rather than focusing on one approach, and this was also noted previously in publication outputs from individual centres.

Three disciplines of biostatistics, sociology and economics were less well represented, with fewer than 40 individuals in total identified for each category. This may reflect the tendency for researchers in these areas to be associated with institutions other than those surveyed (e.g. specific social science or economics institutes) and/or to work on a range of health problems rather than focusing only on malaria. However, consensus opinions from researchers expressed during MIM meetings and the relatively low publication outputs in these areas (Chapter 3) suggest that there is indeed a current lack of expertise in these areas. In view of the importance of biostatistics, sociology and economics in studies to optimize the delivery of healthcare and disease control interventions, these disciplines may require specific encouragement and strengthening through targeted schemes.

Funding sources

Survey data showed that a diverse set of funders contributes towards sustaining malaria research activity in Africa. These included governmental, non-governmental and commercial sources, particularly from Europe. Funds from outside Africa predominated both for research grants (88 per cent of acknowledgements) and for postgraduate studies (54 per cent). Nevertheless, African governmental and local sources accounted for just over half of funding acknowledgements for first degrees and nearly a quarter of PhD and Master's degrees. Local governments

also contribute to sustaining research capacity through the provision of salaries for researchers (68 per cent of acknowledgements) and core support to institutions. Government commitments to scientific research vary considerably between African countries, although current survey data were too limited to establish any clear patterns in this respect.

The observed funding patterns reflect estimates of expenditures on research and development in sub-Saharan Africa, which are amongst the lowest in the world relative to gross domestic product and in absolute terms (UNESCO, 1998). In addition, the current results are consistent with previous studies which estimated that up to 70 per cent of funds for research in some low- and middle-income countries comes from external sources (UNESCO, 1998).

The survey identified the agencies that support the African research base, although data could not provide an accurate measure of relative levels of investment. The World Health Organization and in particular the UNDP/WHO/World Bank Special Programme for Research and Training in Tropical Diseases (TDR),[3] received the highest number of acknowledgements both for research programmes and for Master's and PhD training. French sources (IRD and the Ministry of Cooperation), the European Commission and Scandinavian sources (DANIDA and Sida/SAREC) were other notable contributors to postgraduate training. Figures obtained directly from French agencies (Chapter 2) were incomplete, but the results of the survey of laboratories demonstrate the significant training contribution of these agencies. Although 14 commercial companies were identified as providing research grants, their aggregate contribution accounted for only 6 per cent of the total.

TDR's particular impact in this survey is a reflection of the success of its training schemes, but also in part reflects its major focus on malaria and on least developed countries (Chapter 2). Other substantial supporters of training may not be so visible in this survey due to their particular research subject or geographical remits. Alternatively, a lower-than-expected profile in this survey, may suggest a lack of success in contributing towards a sustainable pool of researchers in Africa. Assessment of individual schemes is required to ascertain the true situation.

[3]The TDR programme is supported by voluntary contributions from governments, international organizations, charities, other non-governmental bodies and the three co-sponsors of the programme- the World Health Organization (WHO), the World Bank and the United Nations Development Programme (UNDP).

Despite the range of varied organizations contributing towards research and training in Africa, over three-quarters of survey respondents expressed the view that there were too few opportunities for Master's and PhD level training. Researchers also felt that opportunities for postdoctoral scientists to obtain independent research grants were very limited. These perspectives are generally supported by the results of the review of training opportunities presented in Chapter 2.

Infrastructure

The survey results indicate that the majority of African malaria research institutions (>90 per cent) are equipped with core facilities, including freezers, centrifuges, incubators and microscopes. In addition, over half of the institutions have access to PCR equipment, suggesting that molecular biology techniques are increasingly becoming standard in African laboratories. However, the views expressed in the opinion survey suggest that current facilities are often inadequate to maintain competitive research programmes: a quarter of respondents highlighted poor infrastructure and laboratory facilities as major obstacles to developing a research career in Africa. Respondents considered that greater and long-term financial investment was essential to tackle this problem. Although 90 per cent of laboratories reported e-mail connections, many survey respondents specified poor telecommunications, computing and library facilities as obstacles to the development of productive international collaborations. The opportunities offered by new electronic communication facilities for dramatically reducing the isolation of African scientists have been recognized by MIM and are being actively pursued.

Field research sites surveyed encompass a range of malaria endemicities and malaria mosquito vector systems. These sites provide an opportunity for coordinated, multi-centre intervention studies, such as vaccine trials or clinical studies, under different transmission intensity conditions. Development of any further field malaria research sites should take into consideration the balance of expertise and epidemiological characteristics at existing sites.

The majority of African scientists surveyed receive their salaries from local sources, but the inadequacy of these salaries was highlighted in

the opinion survey as a major problem that deterred junior scientists from pursuing research careers in Africa. The provision of enhanced salaries, by local or external funders, would provide an incentive to encourage junior researchers to remain in their home countries, and would also allow African researchers to focus on their research without the necessity of seeking additional employment to raise their income to an acceptable level. Salary supplements are in fact provided by a number of organizations, including MIM/TDR awards, and the survey results would support this practice being extended across other organizations.

Training mechanisms and collaborative partnerships

Most African students (90 per cent) completed their first degrees within Africa and this is consistent with the lack of opportunities for Bachelor's training offered by international organizations (Chapter 2). A high proportion (43 per cent) of African scientists carried out their postgraduate training wholly or partly overseas, reflecting a dependence on external funding and the training mechanisms offered by these funders (Chapter 2). This was of concern to respondents in the opinion survey who considered that greater investment in African training centres was necessary to develop sustainable research capacity. Marked variation was observed in the proportion of researchers trained overseas from different countries. For example, a high proportion of researchers in Nigeria and South Africa completed their postgraduate studies in Africa, a factor that is likely to be important in the observed lower international co-authorship in publications for these countries (Chapter 3).

However, African scientists also recognized the critical importance of international partnerships to facilitate effective training of scientists, and sharing of expertise and resources. The existence of mechanisms to support international collaborations was therefore considered a high priority. Training mechanisms that are largely based in the trainee's home country, but allow overseas training attachments were favoured. This approach combines the benefits of both sites, ensuring that the training is relevant to the health problems, facilities and available technologies in the home country, but allowing exposure to leading overseas laboratories.

African scientists further suggested the value of continuing training at postdoctoral level, to allow updating of skills and to maintain links with collaborating laboratories. Improved mechanisms to raise awareness of existing research and training opportunities, and workshops in grant application writing skills were also called for.

Stated collaborations on research grants showed that African researchers collaborate extensively, particularly with researchers in Europe. This was consistent with the results of bibliometric analysis, although the overall extent of collaborations on research grants was lower than on publications (Chapter 3). This lower collaboration rate may be due to the omission of awards held by scientists outside Africa in the survey responses, but it may also indicate that the results of African research activities without an external collaborator are published less frequently in international journals recorded in SCI.

Collaborations across Africa were mainly supported by TDR/MIM awards or grants from the European Commission INCO-DC programme. A slightly higher level of collaboration across Africa was observed from research grants, as compared with publications analysis, but the newly introduced TDR/MIM awards would not have had an impact in the publication years analysed (1995–97).

Overview and policy issues 5

This study has combined a variety of approaches to obtain information on the training opportunities in health and biomedical research in developing regions, and on the status of malaria research capability in Africa. The current chapter aims to draw together the information derived from these different sources and to set out some key issues for consideration in developing strategies to enhance the research bases in developing regions and particularly to strengthen malaria research capacity in Africa.

5.1 INTRODUCTION

Data collected by UNESCO (1996) clearly illustrate the deep divide between established market economies and developing-country regions in terms of their research capacity and productivity: four-fifths of the world's scientists are estimated to reside in Western industrialized nations, Japan and to a lesser extent other large Asian countries. Furthermore, in 1994, developing-country regions together contributed only 6.5 per cent of the world's scientific publications (OST, 1997).

Indigenous research expertise in developing regions is essential for an ultimate impact on health: locally relevant studies are needed to link international research into a national framework of disease epidemiology, health services and population-specific clinical, behavioural and social data. However, resource constraints demand that support for science in developing countries is focused effectively according to policies based on sound analytical data. The present study obtained information on research training opportunities across developing-country regions, and on a number of indicators of malaria research capacity in Africa. Data were derived from questionnaire surveys of funding organizations and of malaria research laboratories in Africa, and also from analyses of malaria publications.

The conclusions and key issues are summarized here together with recommendations for consideration by the Multilateral Initiative on Malaria, by funding organizations and governments in developed and developing regions, and by other coordinating bodies such as the Roll Back Malaria Project of the World Health Organization.

5.2 POLICY ISSUES

International investment and coordination

Scientific research in many developing countries is heavily dependent on foreign investment: the survey of African malaria research laboratories in the present study found that 88 per cent of research grants and 68 per cent of PhD funding acknowledgements were to external sources. These figures indicate the current degree of influence exerted by the policies of foreign investors on research training in Africa, and potentially in other developing regions. However, any capacity-building efforts are ultimately dependent upon local commitment and the establishment of a culture in which science has legitimacy and status.

➤**Funding organizations internationally and governments of developing countries must work together to build sustainable and locally relevant research expertise and facilities. This may require the establishment of formalized, longer-term partnership arrangements.**

The results of the survey of funding organizations indicate that research training offered by higher-income countries to developing regions is generally fragmented and does not represent a coherent international approach to generating scientists to meet health research priorities.

➤**Greater efforts are required to coordinate rational allocation of resources to training activities internationally and to monitor the effectiveness of training programmes. Such a coordination role might be played by a body that involves partnerships between funding organizations internationally, such as the Multilateral Initiative on Malaria (MIM).**

➤**Despite the significance of foreign investment in training scientists in developing countries, the overall expenditure is low relative to training activities in developed regions and represents a small percentage of the activities of some of the larger investors. A slight increase in the proportion of the budgets of larger research or development funders committed to training in lower-income countries could therefore have a substantial overall impact.**

Science is now indisputably a global activity and the issue of retaining developing-country scientists in their home countries, so that their skills can bring benefit locally, must be addressed. In an international market, incentives are required to encourage researchers to remain in their home institutes: national research institutes must compete to retain scientists against overseas centres, as well as with the local private sector. This study showed that nearly 70 per cent of scientists in African malaria research laboratories receive their salaries from local sources, but these salaries were often considered inadequate for a reasonable standard of living.

➤**Governments of developing countries should give serious consideration to the potential large gains of investing in well-targeted research and providing adequate salary structures to reward productive scientists.**

➤**More external funders might also consider provision of salary supplements to scientists who compete successfully for research awards.**

Training mechanisms

International scientific partnerships are an important mechanism for training. The current study has shown that collaborative training links for developing countries are driven substantially by the format of schemes offered by high-income countries. Funding mechanisms tend to link specific countries, with training often being provided in the donor country. Whilst countries must focus their resources in some way, the current situation does not permit optimal use of scientific training opportunities globally and discourages interactions between countries within a region. For example, co-authorships on malaria publications clearly showed the lack of overlap in the African countries with which France and the UK collaborate and the rarity of linkages between Anglophone and Francophone regions of Africa.

➤**There is a need for a greater variety of funding formats to allow diversification of collaborations and more efficient use of scientific strengths irrespective of location.**

➤**Mechanisms to support linkages and networks within developing regions are also required to enable sharing of resources and expertise, and exploitation of local and regional training opportunities. This problem has been recognized by MIM and progress is being made in establishing multi-centre studies within Africa. Additional mechanisms are, however, needed.**

➤**Funding mechanisms that facilitate communication and collaboration with scientists who have migrated overseas will also bring benefit to the home research base.**

In view of the relatively weak research bases in many developing countries, training in high-income countries is still considered to be important in generating internationally competitive scientists. The survey of malaria research centres in Africa showed that half of the scientists in these centres had undertaken their PhD training wholly or partially outside Africa, although there was considerable variation in the extent of overseas training in different African countries.

A consequence of overseas training, however, is that developing-country scientists are often attracted away from their home countries to locations where facilities and career prospects are preferable. In the long-term, therefore, they may be less likely to contribute to the home science base. Moreover, overseas training is expensive and may not be relevant or readily transferable to the home country. Thus, local and regional training is likely to represent an important approach to building sustainable and relevant national research expertise.

➤**The provision of training opportunities in developed countries should be maintained to allow exposure of scientists to internationally competitive laboratories. This might be in the form of shorter overseas training attachments, combined with local and regional training.**

➤**Greater investment in developing countries is required to create 'centres of excellence' that can serve as local and regional training bases. Selection of appropriate centres for development will be essential for efficient use of funds for maximal impact. These centres should be of international scientific standing, and this will require focusing of resources to build top quality facilities and a critical mass of intellectual capacity, preferably in multiple disciplines.**

➤**Regional training is also potentially an important mechanism for building productive research links between neighbouring countries.**

➤**Mechanisms to allow input of teaching and research expertise from overseas scientists at undergraduate through to postdoctoral levels are important in contributing to high-quality training in developing countries.**

➤**Another approach to combining the benefits of local and overseas training is for developing-country centres to register for training through distance learning schemes such as the 'Open University', leading to the award of an overseas degree.**

Analysis of the most productive malaria research centres in Africa, revealed that many of these received sustained and high-level support from external funders, thus illustrating the importance of a stable foundation from which to develop an effective research programme. Most funding organizations link training to major research programmes that have received support through a competitive, peer-reviewed process, an approach that associates training with top quality research studies. In addition, funds are concentrated at specific sites to establish an environment where productive research programmes are more likely to flourish.

An important difficulty is that scientists in developing countries are frequently compelled to undertake major teaching and administrative responsibilities before they have had an opportunity to consolidate their postdoctoral research training. Furthermore, absence of academic and ministry of health staff for training, whether this be locally or overseas, often leaves home institutes short-staffed and increases the burden on remaining staff.

➤**A commitment to research activities by local institutes, for example by ensuring that staff are able to devote adequate time to research activities, is essential for the development of productive research programmes.**

➤**The provision of research fellowships, which include salaries and research expenses, would enable scientists to focus primarily on their research. Such relatively stable funding would also provide a significant incentive for them to pursue a career in research.**

Malaria research is a particular strength of sub-Saharan Africa and data obtained in the present study have shown that a cadre of trained malaria scientists has been established in African research institutes. However, about one-third of identified research groups were led by non-national scientists.

➤**There is a need to develop additional African scientific leaders, but in the interim, the input of committed and able expatriate scientists into training of local scientists should be maximally exploited.**

➤**The information obtained on the location, research specializations and primary sources of funding for malaria research centres should assist both researchers and funders in making optimal use of these centres for further development of research capacity in Africa.**

Career progression opportunities

Very little support from foreign investors is directed at the Bachelor's degree level and the majority of African scientists surveyed in the study completed their first degrees in their home countries.

➤**This observation underscores the responsibility of governments in developing countries to support tertiary education in order to generate a supply of good-quality candidates for research training. Universities in developing regions must also establish degree curricula that reflect the scientific needs of the country and which begin to instil an appreciation of the importance of scientific research.**

Survey of funding agencies and of African malaria research laboratories suggested that current availability of awards for PhD and Master's training, from both local and international sources, is very

restricted. Only 684 PhD awards to scientists across the developing world were identified from the major funders in high-income countries, and 65 per cent of African scientists surveyed indicated that their PhD funding was from an overseas rather than a local government source. By comparison, the opportunities for PhD training per unit population in the UK are nearly 1000 times greater than those in developing countries. Even after taking into account underestimates in the survey figures and the more limited availability of graduates in developing countries, the numbers of PhD awards appear low.

➤**The creation of more opportunities for PhD and Master's training is likely to be beneficial in generating a core of scientific leaders for the future, although adequate support must also be provided for research at the postdoctoral level.**

There is a large overall investment by high-income countries in training attachments, short courses and workshops. This type of training can fulfil an important role but it must be appropriately targeted and monitored for maximal effect.

➤**Further analysis of the nature of current training attachments, short courses and workshops would be valuable to assess the effectiveness of current activities.**

Only a small number of organizations provide opportunities for scientists in developing countries to apply for independent research funds. Local sources of funding are extremely limited and foreign investors tend to provide larger-scale support to groups of researchers, often involving partnerships with external scientists. While this approach can use resources effectively to develop productive research programmes, it is less effective in encouraging individual innovation of local scientists.

➤**The wider availability of individual grants to postdoctoral scientists would provide important career development incentives and may facilitate the emergence of key scientific leaders. Fellowships might involve honorary academic positions to ensure formalized association with local research institutes, and opportunities to input into teaching. Awards might also be linked to larger research grants to ensure that trained individuals are focused together.**

Research specializations

Most countries in the developing world face immense economic and health problems, and it would be inappropriate to advocate increased expenditure across all areas of research, or to aim to duplicate existing major strengths elsewhere in the world. In view of the globalization of science, it is feasible to establish strategies that will allow developing countries to tap into the results of science internationally and build upon these for local benefit. Thus, strategic research priorities for lower-income countries might focus on relevant health problems or aim to exploit unique opportunities.

➤**Mechanisms, at national and international levels, are required to assess the overall distribution of training across different research areas and hence assist in mapping capacity development to research priorities.**

➤**Progress is being made in establishing essential national health research priorities in developing countries, and effective publicizing of these scientific strategies would enable external funders to target research resources more effectively.**

➤**Strengthening of research and control interactions would assist in ensuring that research agendas generate data required to underpin treatment and control strategies, and facilitate rapid uptake of research results into policy and practice. This might require research training experience for public health personnel for example, or involvement of laboratory scientists in service delivery activities.**

African malaria research is currently strongly focused on clinical and field studies, which can yield practical solutions to local problems and these studies are often linked to basic research ongoing in Europe and the USA. Nevertheless, there is growing expertise and facilities within Africa in more fundamental disciplines, showing that many basic science techniques are transferable to Africa where they can complement ongoing clinical and field studies. Basic science is important for innovation and technological breakthroughs and the ongoing growth in these disciplines in developing countries should therefore be encouraged. However, initial targeting should preferably be towards

technologies that are more readily transferable, rather than those requiring major investment in facilities.

➤**Results from the current study suggest that social sciences, health economics and biostatistics are areas that lack expertise in Africa. In view of the importance of these disciplines in optimizing implementation of health interventions and informing policy development, they may require specific strengthening.**

The extent to which the subfield strengths and weaknesses observed for malaria research in Africa can be extrapolated to other research fields or developing regions is difficult to assess. However, broad publications outputs indicate that fundamental biology is a weak field across sub-Saharan Africa, in China and South-East Asia, but is slightly stronger in India and Central Asia and in Latin America. It is estimated that only 8 per cent of research and development expenditure in Africa goes to basic sciences and engineering, as compared with 40 per cent for industrialized countries (OST, 1997).

Measuring progress

Greater efforts to monitor the effectiveness of current research training schemes, at both individual and collective levels, are important to ensure that resources are being used to best effect. Numbers of trained scientists and publication outputs are broad measures of human resources and research productivity. However, research training and capacity-strengthening programmes must be targeted so that they are appropriate to national and regional needs, and assessments should therefore also evaluate the type of expertise generated (disease and disciplinary specializations) and the success of research in producing relevant knowledge. More detailed monitoring of individual capacity-strengthening schemes can also assess indicators such as numbers of grants successfully obtained by trainees, numbers of presentations at conferences, and availability of infrastructure in research institutes.

➤**This report provides valuable baseline data by which to monitor the progress of capacity building efforts in malaria research.**

Effective local and national systems are required to harness the results of scientific research for indigenous development. Early dialogue between external funders, researchers and local governments will assist the effective translation of research results into policy and practice. Clinical and applied research are essential to achieve an impact on health, and accurate measures of the outcomes of these types of research are needed to provide a rationale and justification for investment of resources, by both local and foreign contributors.

➤**The examination of research cited in health policy documents is a potentially effective method of assessing the influence of research in determining clinical practice or disease control strategies. However, in order for this approach to be implemented effectively, policy documents from developing countries must include full bibliographies.**

Local research, often recorded in non-peer-reviewed grey literature, appears to influence national policies for malaria treatment and control.

➤**Greater effort to record grey literature in central, accessible databases, and/or more extensive publication of locally relevant research in peer-reviewed journals would be beneficial.**

The future

There remains a major challenge to build research bases in developing countries that can have a significant impact on health. Funding organizations in developed and developing countries must prioritize and coordinate their activities to use limited resources efficiently in training productive, independent scientists and establishing competitive research facilities. This review provides data on the background context against which funding decisions must be made and it is hoped that it will facilitate an evidence-based approach to capacity building. Partnerships between scientists as well as between funding organizations may be required to achieve significant progress. While there are common themes that are applicable across developing regions, it is clear that there is considerable diversity between individual countries in terms of their educational bases, existing training activities and research facilities. Training strategies will therefore need to be responsive to coun-

try-specific circumstances and opportunities.

Despite the scale of the task ahead, there are positive signs for the future as lower-income countries increasingly recognize the importance of scientific research. For example, countries in the Latin American region have been reforming their science policies (see Macilwain, 1998), and a chain of regional centres of excellence has been proposed to share resources and expertise. China is also an emerging success story, its research productivity having increased very significantly over the last decade under directed governmental policies. Further major reforms have recently been announced (Normile and Lei, 1999), including a threefold increase in salary for scientists, aimed at retaining scientists in China and encouraging those working overseas to return.

There are also positive signs from Africa with an innovative proposal emerging from the World Conference on Science in June 1999. This proposal, which was supported by ministers of science and education from Africa, was to create a science fund for poor countries from the debt relief agreed upon by G8 nations for the world's least-developed countries (Masood, 1999).

5.3 REFLECTIONS ON METHODOLOGIES

This study combined a number of different methods to generate data relevant to international training opportunities for researchers in developing countries, and to malaria research capacity in Africa. These approaches provided different perspectives on the same issue and offered relative advantages and disadvantages. A number of points concerning the techniques employed in the study are set out below to inform future studies.

Assessing funding inputs

Information on funding inputs into malaria research and training was obtained in a number of different ways: from data obtained directly from funding organizations; from funding acknowledgements on research publications and from direct survey of research centres in Africa. Survey approaches in general are time consuming and limited by the extent of coverage of the target population, as well as response rates. Conversely, analysis of publications has the advantage of relative rapidity and can generally achieve systematic coverage of a field. A major advantage of direct survey of funders is that information can be obtained on actual expenditure, whereas numbers of funding acknowledgements on publications do not give an accurate measure of magnitude of funding. The survey of laboratories was not effective in this particular study in obtaining information on levels of financial support, probably due to confidentiality considerations.

The format of records kept by funding organizations is an important factor influencing the success in obtaining relevant data, for example in a specific subject area. Organizations that provide block grants to other institutes or organizations, often do not have centralized records of how this expenditure has been allocated. In this situation, the direct survey of malaria research laboratories was successful in identifying funders which make significant contributions to postgraduate training, but which did not register highly in the funding survey due to incomplete data. The survey of African centres was also able to provide an indication of the relative contributions of local and foreign investors in supporting research and training.

Analysing research outputs

Bibliometrics is a convenient means of measuring research activity in a particular field. However, databases must be selected according to the particular analysis being carried out. For example, MEDLINE has better coverage of clinical research and of non-English language journals compared with the Science Citation Index (SCI), but does not include full details of author addresses, precluding its use in co-authorship analyses. A significant disadvantage of commercially available databases is that they are biased towards research in industrialized countries, as they do not have comprehensive coverage of local and non-English language journals in developing countries or of other types of grey literature.

Standard bibliometric citation techniques for measuring research impact and quality are restricted in their application, since citation indices primarily reflect the influence of research on the scientific community. Research of a more clinical or applied nature is intrinsically disadvantaged in this type of analysis as it receives fewer citations than more basic research.

Alternative approaches are required to assess the success of research in generating new disease interventions or influencing disease treatment or control. Examination of literature cited in malaria treatment and control guidelines could potentially provide a valuable method to assess links between research and policy. However, in the present study it was noted that national guidelines often did not include full references to research results that had guided the development of recommendations. A more systematic approach to citing literature would therefore have to be adopted by countries to allow this approach to be employed more generally.

Assessing human and infrastructural resources

Publications analyses rapidly identified the most productive countries and research centres in Africa, and showed their research specializations and collaboration patterns. However, despite basing analyses on the most recent research outputs, the information was retrospective as it reflected research carried out in the few years prior to publication.

In contrast, the direct survey of active malaria research laboratories gave a current view of research focus and expertise, and identified areas of growth. The survey also provided a more detailed insight into research capacity, including laboratory facilities and the training paths of researchers. Furthermore, the questionnaire gathered the opinions of African scientists with first-hand experience of performing research in Africa. The responses raised issues relating to capacity development that were not evident from the other approaches employed in the study. The breadth of response from research groups was a key feature of this study and the distribution of questionnaires in both English and French was likely to have contributed to the success in obtaining high response rates from both Anglophone and Francophone Africa.

The survey of funding organizations was able to give an overview of the types of awards available in Africa and in other developing regions, and of the numbers of scientists trained annually at different levels. It also provided more detailed information on the strategies of funders in supporting training. However, the survey of African centres was able to give a clear impression of the relative contributions of these schemes towards developing the core of malaria researchers who are currently active in Africa.

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Annexes

1 CONTRIBUTIONS TO THE UNDP/WORLD BANK/WHO SPECIAL PROGRAMME FOR RESEARCH AND TRAINING IN TROPICAL DISEASES (TDR) 1989–98

Contributor	Contribution 1989–98 (US $million)
Norway	42.7
World Bank	40.6
Denmark	26.3
Sweden	25.4
United Nations Development Programme	23.6
USA	22.2
UK	18.6
The Netherlands	17.6
Canada	13.0
Germany	12.3
World Health Organization	11.3
Switzerland	10.6
Belgium	7.8
Australia	6.9
France	3.3
Luxembourg	2.6
Italy	2.0
Japan	2.0
Rockefeller Foundation	1.9
International Development Research Center (Canada)	1.9
Others	11.7
Total	**304.3**

2 CONTACT DETAILS OF FUNDING ORGANIZATIONS

Not all of the organizations listed here offer research training schemes that are open to application. Refer to Chapter 2 for details of support provided.

Agence Universitaire de la Francophonie (AUF)
4, Pl. de la Sorbonne, 75005 Paris, France
Tel: +33 1 44 41 18 18; Fax: +33 1 44 41 18 19
E-mail: recherche@aupelf.refer.org; formation@aupelf.refer.org
Web: www.aupelf-uref.org

Alexander von Humboldt Foundation
Enquiries to: Dr Klaus Manderla,
Alexander von Humboldt-Stiftung
Auswahlabteilung, Jean-Paul-Strasse 12,
D-53173 Bonn, Germany
Tel: +49 228 833 139; Fax: +49 228 833 212
E-mail: ma@avh.de; Web: www.avh.de

Australian Agency for International Development (AusAID)
GPO Box 887, Canberra ACT 2601, Australia
Tel: +2 (0)6206 4000; Fax: +2 (0)6206 4880
Web: www.ausaid.gov.au

Belgian Agency for Development Cooperation (BADC)
Candidates for Master's scholarships are proposed by the Ministry of Health of the developing country. Final selection is by a panel of experts, including a BADC representative.
Rue Bréderode, 6–1000, Brussels, Belgium
Tel: +32 2 519 0211; Fax: +32 2 519 0570

The British Council
Bridgewater House, 58 Whitworth Street, Manchester M1 6BB, UK
Tel: + 44 (0)161 957 7000; Fax: +44 (0)161 957 7111
Web: www.britcoun.org

Burroughs Wellcome Fund
P.O. Box 13901, 21, T W Alexander Drive, Research Triangle Park, NC 27709-3901, USA
Tel: +1 919 991 5100; Fax: +1 919 941 5884
E-mail: info@bwfund.org; Web: www.bwfund.org/

Canadian International Development Agency
200 Promenade du Portage, Hull, Quebec, Canada K1A 0G4
Web: w3.acdi-cida.gc.ca

Centers for Disease Control and Prevention
There are no dedicated awards schemes for developing-country scientists. For information on the Epidemic Intelligence Service (EIS) Program, contact: EIS Program, Epidemiology Programme Office, MS-D 18 CDC, 600 Clifton Road, NE Atlanta, GA 30333, USA
E-mail: eisepo@cdc.gov
Web: www.cdc.gov.epo/dapht/eis/index.htm

Deutscher Akademischer Austauschdienst (DAAD)
Enquiries to: Deutscher Akademischer Austauschdienst
Kennedyallee 50, 53175 Bonn, Germany
Fax: +49 228 882 444
E-mail: postmaster@daad.de; Web: www.daad.de
Alternatively, enquiries may be made to the German Embassy within the country.

DANIDA: The ENRECA programme
The ENRECA Health Network, Department of International Health, Institute of Public Health, Pavillonen 42.1.04. Panuminstituttet, Blegdamvej 3A, DK-2200, Copenhagen N, Denmark
Tel: +45 35 32 76 27; Fax: +45 35 32 76 29
E-mail: enreca@post10.tele.dk
Web: www.um.dk

European Commission
Enquiries to: Dr Mamadou Traoré,
DG XII: INCO-DC programme.
Rue de la Loi 200, 1049 Bruxelles, SDME 11150, Belgium
Tel: +32 2 295 92 71; Fax: +32 2 296 62 52
E-mail: Mamadou.TRAORE@DG12.cec.be; Web: www.cordis.lu

Federal Commission for Scholarships for Foreign Students, Switzerland
Applications to the Swiss diplomatic representative in the country of origin.

Fogarty International Center
Division of International Training and Research
Fogarty International Center, National Institutes of Health, Building 31
31 Center Drive, MSC 2220, Bethesda, MD 20892-2220
Tel: +1 301 496 1653; Fax: +1 301 402 2056
E-mail: jbreman.nih.gov
Web: www.nih.gov/fic/opportunities

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH
Dag-Hammarskjold-Weg 1-5, 65760 Eschborn, Germany
Tel: +49 6196 79 0; Fax: +49 6196 79 1115
Web: www.gtz.de/

INCLEN
INCLEN, Inc. Executive Office, 3600 Market St,
Suite 380, Philadelphia, PA 9104-2644, USA
Tel: +1 215 222 7700; Fax: +1 215 222 7741
E-mail: inclen@inclen.org; Web: www.inclen.org

Institut de Recherche pour le Développement (IRD, formerly ORSTOM)
209–213 rue La Fayette, 75480 Paris Cedex 10, France
Tel: +33 (0)1 48 03 77 77; Fax: +33 (0)1 48 03 08 29
Web: www.ird.fr; www.orstom.fr

International Atomic Energy Agency (IAEA)
International Atomic Energy Agency, PO Box 100, Wagramer, Strasse 5, A-1400 Vienna, Austria
Tel: +43 1 26000; Fax: +43 1 26007
E-mail: official.mail@iaea.org
Web: www.iaea.org

INSERM
Enquiries on Poste Vert awards to: Catherine Schatz, Département des Relations Internationales INSERM,
101 rue de Tolbiac, 75654 Paris Cedex 13, France
Tel: +33 1 44 23 61 81; Fax: +33 1 45.85.14.67
E-mail: novaki@tolbiac.inserm.fr
Web: www.inserm.fr

Institut Pasteur
25-28 Rue du Docteur Roux, 75724 Paris Cedex 15, France
Tel: +33 (0)1 45 68 80 01; Fax: +33 (0)1 45 68 81 86
Web: www.pasteur.fr

2 CONTACT DETAILS OF FUNDING ORGANIZATIONS (cont.)

International Development Research Centre (IDRC), Canada
IDRC has no dedicated award schemes for scientists. Enquiries regarding research in health should be directed to: Dr Enis Baris, Senior Scientific Adviser, Health
Tel: +613 236 6163 ext. 2270; Fax: +613 567 7748
E-mail: ebaris@idrc.ca; Web: www.idrc.ca

Japan International Cooperation Agency (JICA)
Central Office, Shinjuku Mines Tower, 2-1-1, Yoyogi, Shibuya-ku, Tokyo, Japan
Tel: +3 (5352) 5311/5314
Web: www.jica.go.jp

National Institute of Allergy and Infectious Disease (NIAID)
Enquiries to: Elizabeth Higgs, MD, Program Officer, International Tropical Diseases Research Program, NIAID (Solar Building) 6003 Executive Boulevard, Bethesda, MD 20892, USA
Tel: +1 301 496 2544; Fax: +1 301 402 0659
E-mail: EHIGGS@mercury.niaid.nih.gov; Web: www.niaid.nih.gov

Norwegian Agency for Development Co-operation (NORAD)
Applications for NORAD Fellowships for International Diploma and Master's courses to the Norwegian Embassy or Consulate in the country of origin. Fellowships for basic studies are not provided.
Web: www.sui.no

SEAMEO–TROPMED
Enquiries to: The Secretary-General/Coordinator, SEAMEO-TROPMED Network. 420/6 Rajvithi Road, Bangkok 10400, Thailand
Tel: +662 644 4331; Fax: +662 247 7721
E-mail: tmslr@mucc.mahidol.ac.th
Web: www.seameo.org; www.mahidol.ac.th/mahidol/tm/

Sida/SAREC
Enquiries to: Sida, S-105 25 Stockholm, Sweden
Tel: +46 8 698 5000; Fax: +46 8 20 8864
Web:www.sida.se

South African Medical Research Council (MRC)
The MRC is only able to fund researchers who are citizens or permanent residents of South Africa. Researchers in other developing countries who wish to form collaborative ties with South African researchers in relevant fields, should contact MRC programme leaders.
PO Box 19070, Tygerburg 7505, South Africa
Tel: +27 21 938 0911; Fax: +27 21 938 0200
Web: www.mrc.ac.za

South African National Research Foundation (NRF)
PO Box 2600, 001 Pretoria, South Africa
Tel: +27 12 481 4067; Fax: +27 12 481 4010
Web: www.frd.ac.za

Swiss Agency for Development and Co-operation (SADC)
CH-3003, Bern, Switzerland
Web: www.sdc-gov.ch

Swiss National Science Foundation
Wildhainweg 20, Postfach 8232, CH-3001 Bern, Switzerland
Tel: +41 31 308 2222
Web: www.snf.ch

Takemi Program in International Health
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The Wellcome Trust
Enquiries to the Tropical, International or Population Studies Programmes: The Wellcome Trust, 183 Euston Road, London NW1 2BE, UK
Tel: +44 (0)20 7611 8888; Fax: +44 (0)20 7611 7288
E-mail: tropical@wellcome.ac.uk; international@wellcome.ac.uk or population@wellcome.ac.uk; Web: www.wellcome.ac.uk

3 SEARCH STRATEGY TO IDENTIFY MALARIA PAPERS USING THE SCI AND MEDLINE DATABASES

Set	Field
1	Title (ANTIMALARIA* OR MALARI* OR PLASMODIUM OR PLASMODIA*) NOT PHYSARUM
2	Title PROGUANIL OR QUINGHAOSU OR HALOFANTRINE OR AMINOQUINOLINE OR PRIMAQUINE OR ARTESUNATE OR ARTEETHER OR DARAPRIM OR FANSIDAR OR NIVAQUINE OR FANSIMEF OR CAMOQUINE OR CHLORPROGUANIL OR ARTEMETHER OR ARTEMISIN* OR QUININE OR CHLOROQUINE
3	Title MOSQUITOES OR PYRIMETHAMINE OR MEFLOQUINE OR MOSQUITO OR MOSQUITOS OR MOSQUITOCID* OR ANOPHEL*
4	Title AEDES OR SCHISTOSOM* OR ONCHOCERC* OR BRUGIA OR CULEX OR HIV OR LEISHMAN* OR TRYPANOSOM* OR WUCHERERIA OR FILARIA* OR ARBOVIRUS* OR DENGUE OR (YELLOW AND FEVER) OR VIRAL OR VIRUS
5	Set:Article (2 or 3) not (1 or 4)
6	Set: Note (2 or 3) not (1 or 4)
7	Set: Review (2 or 3) not (1 or 4)
8	Set:Article 1
9	Set: Note 1
10	Set: Review 1
11	Set 8 thru 10
12	Set 5 thru 7
	Unconditional set 11
	Conditional set 12

4 AFRICAN PUBLICATION OUTPUT IN SCI AND MEDLINE DATABASES (1995–97)

Country	Number of malaria publications
Kenya	103
Tanzania	74
Nigeria	68
Gambia	56
Cameroon	46
Senegal	44
Gabon	30
Malawi	29
South Africa	29
Burkina-Faso	19
Zimbabwe	19
Ghana	18
Ivory Coast	18
Mali	14
Ethiopia	12
Madagascar	12

Country	Number of malaria publications
Sudan	11
Niger	8
Uganda	8
Burundi	7
Zambia	7
Democratic Republic of Congo (Zaire)	6
Sierra Leone	6
Congo	5
Benin	4
Togo	4
Guinea-Bissau	2
Equatorial Guinea	1
Liberia	1
Somalia	1
Swaziland	1

5 MALARIA CONTROL GUIDELINES AND POLICIES

Country	Title	Authors	Year of publication
Malawi	Guide for the management of malaria (for physicians, clinical officers, medical assistants and nurses	Malaria Control Programme, Ministry of Health and Population	1997
Kenya	National guidelines for diagnosis, treatment and prevention of malaria for health workers	Ministry of Health	1998
Namibia	National policy and strategy for malaria control	Ministry of Health and Social Services	1995
Zimbabwe	National malaria control programme five year plan (1994–1998)	Disease Control Unit, Ministry of Health and Child Welfare	1993
Ghana	Malaria Action Plan – 1993–1997	Ministry of Health	1991
Nigeria	National malaria control programme plan of action 1996–2001	Malaria and Vector Control Division, Federal Ministry of Health	1995
South Africa	Guidelines for the prophylaxis of malaria	Department of Health	1996
South Africa	Guidelines for the treatment of malaria	Department of Health	1996
Zambia	Malaria control programme		1995
Senegal	Programme de lutte contre le paludisme du Senegal	Ministère de la Santé et de l'Action Sociale	1994 (version provisoire)
Tanzania	Plan of Action 1997–2000 of the National Malaria Control Programme	Ministry of Health	1997

6 MALARIA RESEARCH CLASSIFICATION SYSTEM

(A) 1, 2 Antimalarial drug discovery and development *in vitro* and in animal models, and the biochemistry of drug action

1. Antimalarial drug discovery and development *in vitro* and in animal models

Measurement of the activity of potential antimalarial drugs in animal models and *in vitro* models of malaria. Antimalarial drug pharmacokinetic, toxicity and metabolism studies *in vitro* and in animal models. Chemistry and synthesis of antimalarial drugs. Analytical tests for assaying antimalarial drugs.

Excluding: Antimalarial drug pharmacokinetic, toxicity and metabolism studies in humans, trials of antimalarial drugs and combinations of drugs in human malaria patients to establish efficacy (8). Effects of drugs on immune status (3).

2. Mechanisms of drug addition

The biochemistry of drug action on *Plasmodium*. The mechanisms of parasite resistance to antimalarial drugs. Analysis of genes involved in drug resistance. Characterization of drug-resistant strains of *Plasmodium*. Tests for drug susceptibility of parasites.

Excluding: Epidemiology of drug resistance (11).

(B) 3,4 Immunology, vaccine development and vaccine trials

3. Immunology and vaccine development

In vivo and *in vitro* studies on the protective immune response (cellular and humoral) of the mammalian host to malaria. Immune response to particular antigens, including variable antigens. Population studies of human immunity to malaria and the effects of antimalarial drug treatment on immune status. Vaccine development studies and studies of adjuvants for malaria vaccines. Studies on the genetics of the immune response to malaria.

Excluding: Vaccine trials (4). Studies of the pathology of malaria (9). Cloning of candidate vaccine antigens (7). Epidemiology studies of the effects of specific host genotypes on malaria transmission and prevalence (11). Biochemical characterization of vaccine candidate proteins (6).

4. Human vaccine trials and vaccine review articles.

Trials of antimalarial vaccines in humans to establish safety and efficacy. Reviews on the status of antimalarial vaccine development.

Excluding: Preliminary studies of malaria morbidity and mortality in vaccine study area (11).

(C) 5, 6, 7 Biology, biochemistry and genetics of *Plasmodium*

5. Biology of *Plasmodium*

Structure and morphology of different developmental stages. Host–parasite interactions. Biology of invasion of host cells. Localization of parasite proteins or antigens. Culture of parasites. Purification of parasites of parasite stages. Descriptions of species of *Plasmodium* and characterization of malaria strains in animal models (course of infection, susceptibility of different hosts). Studies of rosetting, sequestration and adhesion of infected erythrocytes in which pathological consequences are not examined. *In vitro* studies of interactions between *Plasmodium* and other infectious agents (e.g. EBV).

Excluding: Studies whose primary focus if the pathology of malaria (9). Studies of the molecular basis of host-cell invasion, rosetting and sequestration (6).

6. Biochemistry of *Plasmodium*

Metabolism and nutrition. Enzymology. Translation, processing and export of proteins. Protein sequences, protein and enzyme characterization (including antigen analysis). Glycosylation, GPI anchors, transporters, ion channels, mitochondrial metabolism, electrophysiology studies. Influence of parasite on host-cell biochemistry. Characterization of antigen/protein diversity in strains of *Plasmodium*. Characterization of proteins involved in sequestration and rosetting of infected erythrocytes and of molecular basis for host-cell invasion.

Excluding: Papers primarily on mechanisms of antimalarial drug action (2). Immune response to particular antigens (3). Pathological consequences of parasite sequestration (9).

7. Genetics of *Plasmodium*

Studies on chromosomes. Genomic maps. Genetic crosses. Cloning and sequencing of genes/cDNAs for functional plasmodial proteins (including drug targets and vaccine candidates). Expression of proteins from cloned genes. RNA analyses. Control and timing of expression of genes. Post-transcriptional processing. Genetics of antigenic variability. Techniques for the genetic transformation of *Plasmodium*. Studies of genetic diversity and phylogeny. Tests for genotyping *Plasmodium*.

Excluding: Analysis of the genetics of parasite resistance to antimalarials (2). Epidemiology of antigenic variability (11). Diagnostic tests for detection of malarial parasites (13).

(D) 8,9,10 Clinical treatment and prophylaxis of malaria, and pathophysiology of malaria

8. Clinical management of malaria and antimalarial drug trials

Antimalarial drug pharmacokinetic, toxicity and metabolism studies in humans. Trials of antimalarial drugs and combinations of drugs in human malaria patients to establish efficacy. Drug treatment and prophylaxis recommendations. Development of drug treatment regimens for particular clinical presentations of malaria (e.g. severe malaria, cerebral malaria or malaria during pregnancy, drug-resistant malaria). Case history reports and studies of antimalarial drug side-effects.

Excluding: Malaria prophylaxis recommendations for non-immune travellers to endemic countries (10). Diagnosis and treatment of malaria in non-endemic countries. Studies of social factors influencing drug treatment and compliance. Assessment of long-term prophylaxis in communities in endemic areas. Health services research (12). Reports on drug-resistant strains of *Plasmodium* (11).

9. Pathophysiology and disease symptoms of malaria

Clinical diagnosis of malaria and clinical observations of the disease presentation and pathophysiology of malaria in humans and in animals (e.g. observations on cerebral malaria, malaria during pregnancy, mild malaria). Interactions between malaria and other concurrent infections. The role of nutritional status in determining disease severity. Histopathology of malaria in humans and in animals. The mechanisms of pathology in malaria, including the role of the host immune system, expression of adhesion molecules etc. Studies of the mechanisms by which particular susceptible/resistant mammalian host genotypes exert their effect.

Excluding: Epidemiological studies of malaria prevalence in relation to human genotype (11). Studies linking immunity to malaria to specific genotypes (3).

10. Malaria treatment and prophylaxis in travellers and migrants

Malaria prophylaxis recommendations specifically for short-term visitors to malaria-endemic areas. Diagnosis and treatment of malaria in individuals in non-endemic countries. Case reports of malaria in non-immune travellers to endemic regions. Import of malaria by migrants to non-endemic areas. Prophylaxis in army personnel deployed to endemic areas.

(E) 11. Epidemiology of malaria prevalence and severtiy, and mathematical modelling

Epidemiology of the distribution of species of malarial parasites and mosquito vectors, and of the prevalence of morbidity and mortality due to malaria. Studies of the biological, environmental, social and economic determinants of malaria transmission dynamics and of malaria prevalence (e.g. roles of human behaviour; vector behaviour, ecology and epidemiology; inoculation rates, host genetic factors, *Plasmosdium* strain variation etc.). Epidemiological studies of genetic factors influencing the prevalence of malaria, including sickle cell genes, thalassaemia, HLA type etc. The impact of malaria on selection for particular host genotypes. Epidemiology of resistant/susceptible strains of *Plasmodium* to antimalarial drugs and of mosquito vectors to insecticides. Mathematical modelling of malaria (e.g. of malaria transmission and of human immune response to malaria).

Excluding: Studies of the effects of control interventions on malaria transmission. Morbidity and mortality as a result of malaria (12). Studies on the mechanisms by which specific mammalian host genotypes influence host immunity (3) or pathology (9). Studies of vector ecology and behaviour which are not in the context of transmission (14). Cases of malaria imported to non-endemic areas (10).

(F) 12. Intervention trials and health services research

Trials to test measures for the control of mosquito vectors (bednets, environmental and biological control measures, insecticides etc.) and to test other interventions, administered through health care services etc. For the control of malaria morbidity and mortality in communities (e.g. drug treatment and prophylaxis). Studies of community attitudes, knowledge and practice in relation to malaria treatment and control programmes. Healthcare service studies in relation to delivery of malaria treatment and control measures. Design of treatment and control programmes appropriate to local prevailing conditions. Implementation and evaluation of large-scale malaria treatment and control programmes operated through healthcare services, government ministries, non-governmental organizations etc. Operational research. Economic impact of malaria morbidity and mortality on communities and the economics of malaria control measures.

Excluding: Clinical trials of drugs or vaccines to establish safety and efficacy (8 or 4).

(G) 13. Development of diagnostic tests for malaria

Diagnostic tests for the detection and identification of malarial parasites in humans: ELISAs, DNA probes, PCR tests, novel microscopy tests etc.

Excluding: Application of these tests in epidemiology studies (11). Tests for genotyping parasites (7).

(H) 14. Studies of mosquito vectors of malaria

Vector biology, biochemistry and genetics. Including studies of vector susceptibility to infection by *Plasmodium*, genetic transformation of vectors, insect transposable elements, genetics of insecticide resistance, tests for vector identification, taxonomy and systematics. Development of tests for the identification of *Plasmodium*-infected mosquitoes. Characterization of mosquito behaviour and ecology.

Laboratory-based studies to develop mosquito control measures. Studies of parasites and pathogens of mosquitoes, including those which might be applied as biological control agents.

Excluding: Studies primarily on biology of parasite interaction with mosquito host (5). Studies in which the epidemiology and behaviour of vectors is specifically related to the transmission of malaria (11). Field testing of mosquito control measures (12).

Definition of 'human' and 'non-human' research

Publications or grant awards were classified as 'human' if they included within them studies of malaria in humans. For example: clinical management and clinical observations of malaria in humans, the human immune response to malaria, human genetic susceptibility to malaria, the prevalence of morbidity and mortality due to malaria, malaria control and treatment studies in populations (including mosquito control programmes), epidemiology of antimalarial drug resistance, health services research.

All research into animal species of *Plasmodium* and studies of human parasites *in vitro* were classified as 'non-human'. This category also included basic science studies of mosquito vectors of malaria, studies of clinical disease or pathology in animals, theoretical mathematical modelling of malaria, studies of the epidemiology of mosquito vectors and vector behaviour studies.

7 ACKNOWLEDGEMENTS BY FUNDING BODY FOR PAPERS (INTERNATIONAL AND AFRICAN) FROM 1995–97

Number of papers with at least one acknowledgement to a funding body (Percentage of all papers with funding acknowledgements)

International (total number of papers with funding acknowledgements = 2034)

Funding body	Papers	
UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR)	388	(19%)
Wellcome Trust, London, UK	234	(12%)
US Department of Defense (DoD)	231	(11%)
US National Institute of Allergy and Infectious Diseases (NIAID)	184	(9%)
US National Institutes of Health (NIH)	169	(8%)
UK Medical Research Council	160	(8%)
European Commission	141	(7%)
Centers for Disease Control and Prevention (CDC USA)	115	(6%)
US Agency for International Development (USAID)	107	(5%)
Institut Pasteur, Paris	103	(5%)
Australian National Health and Medical Research Council	91	(4%)
World Health Organization (WHO)	90	(4%)
Institut National de la Santé et de la Recherche Médicale (INSERM)	75	(4%)
Kenya Medical Research Institute (KEMRI)	71	(4%)
Centre Nationale de la Recherche Scientifique (C N R S)	75	(4%)
Hoffmann-La Roche	58	(3%)
John D and Catherine T MacArthur Foundation	49	(2%)
Indian Council of Science and Industrial Research	49	(2%)
Swiss Tropical Institute (STI)	47	(2%)
Fonds National Suisse de la Recherche Scientifique (FNSRS)	43	(2%)
L'Institut de Recherche pour le Développement (IRD) formerly ORSTOM	43	(2%)
Deutsche Forschungsgemeinschaft (DFG)	37	(2%)
Japanese Ministry of Education, Science and Culture	37	(2%)
National Research Council, Brazil	35	(2%)
Swedish Medical Research Council	32	(2%)
Howard Hughes Medical Institute	31	(2%)
SmithKline Beecham plc	29	(1%)
Foundation for the Advancement of Science, Denmark	28	(1%)
Papua New Guinea Government	24	(1%)
Swedish Agency for Research Development with Other Countries (SAREC)	23	(1%)
Rockefeller Foundation, New York	22	(1%)
Pan-American Health Organization	20	(1%)
Danish Agency for International Development (DANIDA)	19	(1%)
Recherche et L'Espace, Ministère de la France	18	(1%)
Ministère de Cooperation et du Développement, France	18	(1%)
Thai Government	18	(1%)
Colombian Government	18	(1%)
Burroughs Wellcome Fund, USA	17	(1%)
US Public Health Service, Rockville MD	17	(1%)
Ministère de Recherche et de la Technologique, France	17	(1%)
Medical Research Council, Canada	16	(1%)
UK Department of Health	15	(1%)
Oswaldo Cruz Foundation, Brazil	15	(1%)
Brazillian Agency for the Funding of Studies and projects	14	(1%)
Tanzanian Government	14	(1%)
Biotechnology and Biological Sciences Research Council (BBSRC), UK	13	(1%)
Royal Society, London	13	(1%)
Cameroon Government	13	(1%)
Canadian National/Natural Science and Engineering Research Council (NSERC)	13	(1%)
National Science Foundation, USA	12	(1%)
Fonds der Chemischen Industrie, Frankfurt am Main	12	(1%)
Indonesian Government	12	(1%)
Queensland Institute for Medical Research	12	(1%)

African (total number of papers with funding acknowledgements = 410)

Funding body	Papers
UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR)	97 (24%)
Wellcome Trust	79 (19%)
Kenya Medical Research Institute (KEMRI)	71 (17%)
UK Medical Research Council	63 (15%)
Centers for Disease Control and Prevention (CDC USA)	39 (10%)
L'Institut de Recherche pour le Développement (IRD) (formerly ORSTOM)	35 (9%)
US Agency for International Development (USAID)	33 (8%)
World Health Organization (WHO)	33 (8%)
Swiss Tropical Institute (STI)	31 (8%)
US Department of Defense (DoD)	28 (7%)
European Commission	25 (6%)
Institut National de la Santé et de la Recherche Médicale (INSERM)	22 (6%)
Institut Pasteur (IP)	22 (5%)
Ministère de Cooperation et du Développement, France	18 (4%)
Danish Agency for International Development (DANIDA)	14 (3%)
Swedish Medical Research Council	14 (3%)
US National Institutes of Health (NIH)	13 (3%)
Cameroon Government	13 (3%)
Swedish Agency for Research Development with Other Countries (SAREC)	12 (3%)
Tanzanian Government	12 (3%)
US National Institute of Allergy and Infectious Diseases (NIAID)	11 (3%)
Hoffmann-La Roche	10 (2%)
Rockefeller Foundation	10 (2%)
South African Medical Research Council	9 (2%)
Danish Medical Research Council	7 (2%)
US Government	7 (2%)
Centre Nationale de la Recherche Scientifique (CNRS)	6 (2%)
Ministère de Recherche et L'Espace, France	6 (1%)
Swiss Directorate for Technical Cooperation and Humanitarian Aid	6 (1%)
Fonds National Suisse de la Recherche Scientifique (FNSRS)	6 (1%)
Deutsche Forschungsgemeinschaft (DFG)	6 (1%)
SmithKline Beecham plc	6 (1%)
Burkina-Faso Government	6 (1%)
Gambian Government	5 (1%)
Swedish National Board for Laboratory Animals	5 (1%)
Swedish International Development Cooperation Agency (Sida)	5 (1%)
UK Department of Health	5 (1%)
Ethiopian Government	5 (1%)
Foreign Affairs, Ministry of The Netherlands	5 (1%)
Ministère de Recherche et de la Technologique, France	4 (1%)
Netherlands Foundation for Advancement of Tropical Research (WOTRO)	4 (1%)
Swedish Institute	4 (1%)
Japan International Co-operation Agency (JICA)	4 (1%)
Malawian Government	4 (1%)
UNICEF	4 (1%)
Fonds der Chemischen Industrie, Frankfurt am Main	4 (1%)

8 QUESTIONNAIRE FOR THE SURVEY OF AFRICAN MALARIA RESEARCH LABORATORIES

Section A: Completed by leaders of research groups

Section A: (i) About your research group

(a) Name of head of research group. . . . . .

(b) Title of research group. . . . . .

(c) Address of institute . . . . . .

. . . . . .

(d) What proportion of the group's time is currently spent on malaria research?

0–25% ☐ 26–50% ☐

51–75% ☐ 76–100% ☐

(e) Please give details of all grants (including sources of local funding) that have supported research in your group over the last 5 years (1993 to date) in any subject.

All data will be treated in strict confidence.
Data will not be attributed to individuals and will be used in aggregate.

1. Funding body/source . . . . . .

   Award title . . . . . .

   Dates of award (from/to). . . . . Amount*. . . . . .

   Other collaborating institutes involved in research project (if applicable): . . . . . .

2. Funding body/source . . . . . .

   Award title . . . . . .

   Dates of award (from/to) . . . . . Amount*. . . . . .

   Other collaborating institutes involved in research project (if applicable): . . . . . .

3. Funding body/source . . . . . .

   Award title . . . . . .

   Dates of award (from/to). . . . . Amount*. . . . . .

   Other collaborating institutes involved in research project (if applicable): . . . . . .

* "Amount of funding" need not be completed, but approximate figures would be very useful.

8 QUESTIONNAIRE FOR THE SURVEY OF AFRICAN MALARIA RESEARCH LABORATORIES (cont.)

Section A: (ii) Your staff

(a) How many RESEARCH STAFF? (Number)

i) Currently work in your research group? . . . . . .

ii) Are involved in malaria related research? . . . . . .

(b) Please complete or update the information in the following chart taken from the Directory of the African Malaria Vaccine Testing Network.

Number of employees in each of the following specialities:

Specialities	MD	Diploma	1st Degree	Master's	PhD	African National	Non-African National	TOTAL
Public Health								
Epidemiology								
Parasitology								
Entomology								
Immunology								
Biochemistry								
Molecular Biology								
Biostatistics								
Sociology								
Economics								
Demography								
Other discipline (please specify)								
Number of technical staff								
TOTAL								

Section B: Completed by individual researchers

Section B: Staff details: To be completed by individual researchers, who are qualified to at least first degree level.

Please complete the following questions giving details of all academic and training qualifications you hold and return to the head of your research group.

The purpose of the questionnaire is to gather information on research funding and training opportunities in tropical medicine, with a particular focus on malaria in Africa. All data will be treated in strict confidence. Data will not be attributed to individuals and will be used in aggregate. You need not indicate your name on this form if preferred.

(a) Name . . . . . .

(b) Department/Institute . . . . . .

(c) Current job title . . . . . .

(d) Nationality . . . . . .

(e) Current employment . . . . . .

8 QUESTIONNAIRE FOR THE SURVEY OF AFRICAN MALARIA RESEARCH LABORATORIES (cont.)

(i) Do you have a permanent position? Yes ☐ No ☐ If no, please answer Question (ii)

(ii) For how long is your employment contract? ☐ months

(iii) Who funds your salary? . . . . . .

(iv) Who funds your research? . . . . . .

(f) What proportion of your time is currently spent working on malaria?

0–25%	☐	26–50%	☐
51–75%	☐	76–100%	☐

(g) Academic qualifications (e.g. undergraduate, higher degrees and diplomas, Postdoctoral research experience and research training attachments). MOST RECENT FIRST

Qualification and subject title: . . . . . .

Dates of study/training attachment: . . . . . .

Location(s) of study/training (Institute, country): . . . . . .

Source of funding: . . . . . .

Amount of funding*: . . . . . .

From: . . . . . .

To: . . . . . .

*"Amount of funding" may be left blank if preferred, but approximate figures would provide valuable information for the MIM survey. Please copy this sheet if necessary

(h) Do you have any collaborative or training links with other institutions or organizations involved in malaria research or control activities? If yes, please give full details (e.g. location of collaborating institute, nature of link). Please mention any local opportunities for malaria research training that currently exist or are under consideration.

(i) What types of schemes (e.g. collaborative, training, funding etc.) do you consider, are or would be, particularly beneficial in developing research capacity in African universities, research institutions and ministries of health? Please give details of level of training (MSc, PhD etc.), mechanism, location etc.

(j) Please identify any specific difficulties that you may have experienced in developing and maintaining a research career in tropical medicine. How might these difficulties be overcome in the future?

Please continue on additional sheet if more space is required.

Thank you for your co-operation in completing this questionnaire

9 SURVEY RESPONDENTS

Country	Institute	Research groups (*n*)	Section B respondents (*n*)
Benin	Regional Centre for Epidemiological Research of Cotonou	1	2
Burkina-Faso	Centre National de Lutte contre le Paludisme, Ouogadougou	1	7
Burkina-Faso	Centre Muraz, Bobo Dioulasso	1	5
Cameroon	Georgetown University, University of Yaoundé	1	18
Cameroon	Institute of Medical Research and Studies of Medicinal Plants, Yaoundé	1	9
Cameroon	University of Buea	1	13
Cameroon	L'Organisation de Coordination pour la Lutte contre les Endémies en Afrique (OCEAC), Yaoundé	2	7
Ethiopia	Jimma Institute of Health Sciences	1	7
Ethiopia	Ethiopian Health and Nutrition Research Institute	1	4
Gabon	Albert Schweitzer Hospital, Lambaréné	1	3
Gabon	Centre International de Recherches Médicales de Franceville	1	2
The Gambia	UK Medical Research Council Laboratories, Fajara	1	10
Ghana	Navrongo Health Research Centre	1	15
Ghana	Noguchi Memorial Institute, Legon	2	10
Ivory Coast	Institut Pasteur de Côte d'Ivoire	1	4
Ivory Coast	Institut Pierre Richet, Bouaké	1	18
Kenya	KEMRI Vector Biology and Control Research Centre, Kisumu	1	11
Kenya	KEMRI–Wellcome Trust collaborative programme, Kilifi and Nairobi	3	25
Madagascar	Institut Pasteur de Madagascar	2	11
Malawi	Community Health Sciences Unit, Ministry of Health, Lilongwe	1	4
Malawi	Wellcome Trust Research Laboratories, College of Medicine, Blantyre	1	3
Niger	Centre de Recherche sur les Meningites et les Schistosomoses (CERMES), Niamey	1	8
Nigeria	University of Ibadan	2	15
Nigeria	College of Medicine, University of Lagos	1	6
Nigeria	University of Nigeria, Nsukka	1	6
Senegal	Institut Pasteur de Dakar	4	14
Senegal	Institut de Recherche pour le Développement, Dakar	1	12
Senegal	Faculty of Medicine and Pharmacy, Dakar	1	6
South Africa	National Malaria Research Programme, Durban	1	7
South Africa	South African Institute of Medical Research, Johannesburg	1	4
South Africa	University of Cape Town	1	1
South Africa	University of Natal	1	2
Sudan	Institute of Endemic Diseases, University of Khartoum	1	9
Tanzania	Amani Medical Research Centre	1	10
Tanzania	Muhimbili College of Health Sciences	1	1
Tanzania	National Institute for Medical Research, Dar es Salaam	1	3
Uganda	Med Biotech Laboratories, Kampala	1	8
Zimbabwe	Blair Research Institute, Harare	1	9
Individual questionnaires from African researchers working abroad		0	2

Additional data from AMVTN Directory included in analysis of research expertise

Kenya	Division of Vector Borne Diseases, KEMRI, Nairobi
Mozambique	Instituto Nacional de Saude, Maputo
Sudan	The Blue Nile Research and Training Institute
Tanzania	Ifakara Health Research and Development Centre
Togo	National Malaria Control Programme, Ministry of Health, Lomé
Zambia	Tropical Diseases Research Centre, Ndola

10 FUNDING SOURCES LISTED BY RESPONDENTS TO A SURVEY OF AFRICAN MALARIA RESEARCH LABORATORIES

Funder	Research grants 1993–98	Funding acknowledgements for current research
UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR)[1]	61	80
French Ministry of Cooperation	33	26
World Health Organization (WHO)[1]	25	31
Home government	24	94
Wellcome Trust	20	20
European Commission	17	25
Agence Universitaire de la Francophonie (AUPELF-UREF)	9	8
Unidentified funding bodies	9	11
Institut Pasteur	8	15
Danish International Development Agency (DANIDA)[2]	7	14
International Development Research Center, Canada	6	6
US National Institutes of Health	5	17
UK Department for International Development (DFID)	5	4
Swedish International Development Cooperation Agency (Sida/SAREC)	4	1
Roche	4	1
United Nations Children's Fund (UNICEF)	4	0
US Agency for International Development (USAID)	3	8
US Department of Defense	3	3
Rockefeller Foundation	3	3
Italian Government	3	3
World Bank	2	4
International Atomic Energy Agency	2	3
SmithKline Beecham	2	2
International Center for Genetic Engineering and Biotechnology (ICGEB)	2	2
Centre National de la Recherche Scientifique (CNRS)	2	2
Japan International Cooperation Agency (JICA)	2	1
Agr Evo	2	0
UK Medical Research Council	1	9
The Netherlands Government	1	3
Pasteur Merieux Connaught	1	3
Sumitomo	1	1
Glaxo Wellcome	1	1
Rhône Poulenc	1	0
Parke Davis	1	0
Old Mutual	1	0
Medicus Mundi	1	0
Laboratoire Innotech International	1	0
L'Institut de Recherche pour le Développement (IRD)[3]	1	22
Institut National de la Santé et de la Recherche Médicale (INSERM)	1	0
Hoffman-La Roche	1	0
German Government	1	0
Belgian Government	1	0
Bayer	1	0
Water Aid	1	0
US Centers for Disease Control and Prevention (CDC)	0	8
Self	0	8
University of Tubingen, Germany	0	3
Swiss Agency for Development Cooperation (SDC)[4]	0	3
Inter-church Medical Assistance	0	2
Association pour le Développement de la Riziculture en Afrique de l'Ouest (ADRAO)	0	1
Canadian International Development Agency (CIDA)	0	1
German Government	0	1
Norwegian Government	0	1
Volkswagen	0	1
Zeneca	0	1

[1] Research grants specifically acknowledging the UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR) were analysed separately from other acknowledgements to the World Health Organization

[2] Includes acknowledgements to the Danish Bilharziasis Laboratory

[3] Formerly ORSTOM

[4] Includes acknowledgements to Swiss Tropical Institute

11 FUNDING ACKNOWLEDGEMENTS FOR MASTER'S AND PHD TRAINING IN A SURVEY OF AFRICAN MALARIA RESEARCH LABORATORIES

Funder	PhD	Master's
Home government	23	50
UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR)[1]	23	26
Self	15	37
Institut de Recherche pour le Développement (IRD)[2]	10	12
French Ministry of Cooperation	6	5
European Commission	5	3
Wellcome Trust	5	3
Agence Universitaire de la Francophonie	4	0
Danish International Development Assistance (DANIDA)[3]	4	1
Swedish International Development Assistance (Sida/SAREC)	4	0
US National Institutes of Health	3	2
IDRC	2	1
Swiss Agency for Development and Cooperation (SDC)[4]	2	4
US Centers for Disease Control and Prevention	2	3
US university scholarships	2	2
USAID	2	1
British Council	1	1
CIDA	1	2
Deutscher Akademischer Austauschdienst (DAAD)	1	2
Edna McConnell Clark Foundation	1	0
Institut Pasteur	1	2
International Atomic Energy Agency	1	0
Italian Government	1	0
Japanese Government	1	1
Netherlands Government	1	0
Rudolf Geigy Foundation	1	0
UK Medical Research Council	1	0
United Nations	1	1
Chinese Government	0	1
Government of the former Soviet Union	0	2
Indonesian Government	0	1
NORAD	0	1
UK Department for International Development	0	3
Unknown/not specified	10	13

[1] Research grants specifically acknowledging the UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR) were analysed separately from other acknowledgements to the World Health Organization

[2] Formerly ORSTOM

[3] Includes acknowledgements to the Danish Bilharziasis Laboratory

[4] Includes acknowledgements to Swiss Tropical Institute

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