FREEDOM TO INNOVATE
BIOTECHNOLOGY IN AFRICA'S DEVELOPMENT

Draft Report of the High-Level African Panel on Modern Biotechnology of the African Union (AU) and the New Partnership for Africa's Development (NEPAD)

July 14, 2006

About the African Union (AU)

The Africa Union (AU) was born out of the 9th September 1999 Declaration (the Sirte Declaration) issued by the Heads of State and Government of the Organisation of African Unity (OAU) which called for the establishment of an African Union to accelerate the process of integration in the continent. It was established to play a dual role of catalysing Africa's participation in the global economy and addressing multifaceted social, economic and political problems which would have negative aspects on globalisation. The AU is based on the common vision of a united and strong Africa and on the need to build a partnership between governments and all segments of civil society, in particular women, youth and the private sector, in order to strengthen solidarity and cohesion amongst the peoples of Africa. As a continental organization it focuses on the promotion of peace, security and stability on the continent as a prerequisite for the implementation of the development and integration agenda of the AU.

About the New Partnership for Africa's Development (NEPAD)

The New Partnership for Africa's Development (NEPAD) is a socio-economic development programme of the AU) It is a new vision of African leaders in their quest for a socio-economic renewal of the entire continent. This initiative was adopted at the AU Summit in Lusaka, Zambia, 2001. African Heads of State and Government realize that Africa can only take its proper place in the international community if it gains economic strength, hence the objective of NEPAD is to stimulate Africa's development by bridging existing gaps in priority sectors which include agriculture, health, education, infrastructure, information and communication technology, environment, tourism, science and technology, African Peer Review Mechanism and private sector and civil society. The key NEPAD principles and messages are: African ownership and responsibility for the continent's development; the promotion and advancement of democracy, human rights, good governance and accountable leadership; self-reliant development to reduce dependency on aid; building capacity in African institutions; promoting intra-Africa trade and investment; accelerating regional economic integration; advancing women; strengthening Africa's voice in international forums; and forging partnerships with African civil society, the private sector, other African countries and the international community..

High-Level African Panel on Modern Biotechnology

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Preface

African governments have recognized the importance of regional cooperation to address possibilities and the range of issues associated with biotechnology and genetic modification. Within the framework of the New Partnership for Africa's Development (NEPAD) they have resolved to promote programmes that will generate a critical mass of technological expertise in targeted areas that offer high growth potential from biotechnology and the second is to harness biotechnology in order to develop Africa's rich biodiversity and improving agricultural productivity and developing pharmaceutical products.

In the context of the African Union (AU), African leaders resolved to take a common approach to address issues pertaining to modern biotechnology and biosafety by calling for an African common position on biotechnology.

This report is about the role of modern biotechnology in the transformation of African economies. It examines how a wide range of opportunities presented by biotechnology can be tapped by African countries. It focuses on how best to build the capacity needed to harness and apply the technology to improve agricultural productivity, public health, increase industrial development and economic competitiveness and promote environmental sustainability in Africa. The report also takes into account the importance of promoting the conservation and sustainable utilization of Africa's biodiversity.

The main message of this report is that regional economic integration in Africa should embody the building and accumulation of capacities to harness and govern modern biotechnology. Regional economic integration bodies are key institutional vehicles for mobilizing, sharing and using existing scientific and technological capacities, including human and financial resources as well as physical infrastructure for biotechnology R&D and innovation. The loci of action are primarily local innovation areas which have core research and business institutions. International partnerships in biotechnology are critical to the realization of Africa's biotechnology strategies and should be pursued aggressively.

The Panel draws it recommendations from analysis of the current research and development on the continent and outside Africa and some of the emerging social, economic, legal and political issues that surround the development, dissemination and marketing of biotechnologies and their products.

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Acronyms

AATF	African Agricultural Technology Foundation
ACP	African, Caribbean, and Pacific
ADB	African Development Bank
AGERI	Agricultural Genetic Engineering Institute (Egypt)
AIA	Advance Informed Agreement
AMCOST	African Ministerial Council for Science and Technology
APB	High-Level African Panel on Modern Biotechnology
ARC	Agricultural Research Council (South Africa)
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
AU	African Union
BIO-EARN	East African Regional Program and Research Network for Biotechnology, Biosafety, and Biotechnology Policy Development
BioPAD	Biotechnology Partnership and Development (South Africa)
Bt	Bacillus turingiensis
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize and Wheat Research Centre
COMESA	Common Market for Eastern and Southern Africa
CORAF/WECARD	Conseil Ouest et Centre Africa pour la Recherche et le Developpement Agricoles / West African Council for Agricultural Research and Development
CSIR	Council for Scientific and Industrial Research (South Africa)
ECOWAS	Economic Community of West African States
EDCTP	European and Developing Countries Clinical Trials Partnership
FAO	Food & Agriculture Organisation of the United Nations
GMOs	Genetically Modified Organisms
ICTTD	Integrated Consortium on Ticks and Tick-borne Diseases
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
IPR	Intellectual Property Rights
ISAAA	International Service for the Acquisition and Application of Agricultural Biotechnology
LMOs	Living Modified Organisms
MNCs	Multinational Corporations
NEPAD	New Economic Partnership for Africa's Development
OAU	Organisation of African Unity
OECD	Organization for Economic Cooperation and Development
R&D	Research & Development
RECs	Regional Economic Communities
SADC	Southern African Development Community
SMEs	Small and Medium Enterprises
SPS	Sanitary and Phyto-sanitary
TBT	Technical Barriers to Trade
TRIPS	Trade-related Aspects of Intellectual Property Rights
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
WHO	World Health Organization
WTO	World Trade Organization

Executive Summary

The history of Africa has been marked by a unique development narrative in which science, technology and innovation have often been viewed as a preserve for a select few rather than as tools for development in negative terms. But this narrative is starting to change and African leaders are starting to view science, technology and innovation as critical to human development, global competitiveness and ecological management. In a new vision for the continent, African leaders are focusing on measures that promote their "freedom to innovate" in all fields of human endeavour in general and in science and technology in particular. It is in this context that the findings and subsequent implementation of the recommendations of the High-Level African Panel on Modern Biotechnology of the African Union and the New Economic Partnership for Africa's Development (NEPAD) should be viewed.

The outcome of the work of the panel is the nurturing of "regional innovation communities" involving groups of countries in eastern, western, northern and southern Africa operating in the framework of designated Regional Economic Communities (RECs). The innovation communities may be anchored in "local innovation areas" with clusters of capabilities in agricultural, health, industrial and environmental biotechnologies. The strategies will be implemented through RECs whose capacity will in turn need to be strengthened.

To elaborate on this focus, the report: (a) outlines the role of technology in general and modern biotechnology in particular in regional economic integration and trade; (b) outlines priority areas in modern biotechnology of relevance to African development; (c) identifies critical capabilities needed for the development and safe use of modern biotechnology; (d) specifies harmonized regulatory measures needed for advancing research and commercialization, safe use and trade; and (e) proposes strategic options for creating and building regional biotechnology innovation communities and local innovation areas in Africa.

Biotechnology development and implications

Advances in biotechnology offer considerable opportunity for addressing many of Africa's pressing challenges in fields related to human development, international trade, and ecological management. The ability of African countries to benefit from these advances will depend largely on the extent to which they align their development policies and governance structures with the imperatives of technological innovation. More specifically, these countries will need to place science, technology and innovation at the centre of their development strategies and focus of promoting regional economic integration and trade. Of particular relevance will be strategies that emphasize the creation of "regional technological communities" involving families of proximate countries as well local innovations areas which are dedicated to using biotechnology to solve local problems.

Countries should (1) facilitate the process of regional integration; and (2) consider technological cooperation as a vehicle for promoting regional integration. Countries and emerging RECs should (1) identify biotechnology-related areas of competitive advantage; and (2) facilitate local innovation centre upgrading initiatives for economic development. Countries and emerging RECs should identify ways of improving cooperation with other regions (particularly Asia and Latin America) of the world to effectively address issues pertaining to modern biotechnology.

Priority Areas

Biotechnology research in Africa focuses largely on seeking to solve local problems associated with food production, nutrition enhancement, health improvement, ecological restoration, energy production as well as the production of specialty products. These priority areas differ from region to region and therefore offer unique opportunities for both specialization and cooperation across the continent. Furthermore, the prospects of using emerging platform technologies to address diverse problems offers new opportunities for technological cooperation between African countries and other regions of the world while reducing the potential for competition in end-uses of shared technologies. In other words, Africa's "distance" from the centres of technological origin is a source of creativity in applying existing technologies to new uses and therefore expands the prospects for international cooperation.

Countries must focus increased policy attention on the use of existing technologies like biotechnology, which potentially have broad implications for the economy, while building a foundation for long-term R&D activities. African policymakers must consider how biotechnology policies can supplement and strengthen existing economic, industrial, health care, and environmental policies. Countries must seek to develop capacities in all platform technologies whose combined impact will have profound implications for long-term economic transformation. Countries must also seek to integrate biotechnology policies into overall national development policy frameworks while reducing resistance to its adoption, diffusion, and integration within economically-important sectors.

African countries and regions must invest in agricultural biotechnology projects and capacity-building to address long-term issues of hunger, nutrient deficiency, and threats to overall agricultural productivity caused by unfavourable climate, diseases, and soil infertility. African political, research, and higher education institutions must invest in animal biotechnology R&D to stem the increasing prevalence of livestock diseases and infection.

Africa must upgrade and expand its limited forestry biotechnology programs for economic benefits to be reaped in the world economy. African countries and regions should: (1) study the major players contributing to innovation in health biotechnology, including those in the private sector, with a particular focus on knowledge flows and value creation; (2) identify strengths and weaknesses in efficient use of resources, for example, ways of joint decision-making among different ministries and; (3) analyze the close linkages between macroeconomics and health. Health is an intrinsic human right as well as a central input to poverty reduction and socioeconomic development. Africa should develop a comprehensive industrial biotechnology R&D agenda and fast track its program to create the enabling environment for effective private sector participation in the development of bio-fuels.

African countries and regions should more fully integrate environmental biotechnology into its environmental protection strategies and policies and launch pilot-scale production of environmentally friendly products including food, fibre, cosmetics, pharmaceutical and products for biological management of pests.

Critical capacities

Africa's ability to effectively use existing and emerging biotechnologies will depend largely on the level of investment in building physical, human, institutional and societal capacities. More specifically, Africa's regional innovation communities will need to specifically focus on creating and reforming existing knowledge-based institutions, especially universities, to serve as centres of diffusion of new technologies into the economy. Building such critical capacities will also entail consideration of international cooperation as well as complementary reforms in the structure and conduct of international development cooperation agencies. Issues such as investment in higher education, promotion of business development and support for research and development will need to acquire greater standing in international cooperation programs. In other words, development cooperation will need to shift from dependence on relief models to a new emphasis on competence-building. Investing in critical capabilities is central to Africa's ability to benefit from its resources.

Develop and expand national and regional human resources development strategies that include: (1) a continental biotechnology curriculum that focuses on specific areas and targets that offer high economic potential for the regions and the continent; (2) a consortium of clearly identified and designated universities that should develop and offer regional biotechnology training courses; (3) a focus on female recruitment in the sciences and engineering. Africa should immediately expand and create infrastructure development programs that upgrade strategically important infrastructure in order to tap into the opportunities that may arise from biotechnology. Research and development activities for the development, operation and maintenance of infrastructure should also be promoted, and linkages should be established with both domestic and overseas research networks. African countries should identify specific biotechnology priority areas that offer high potential for regional R&D and product development and integrate these priorities into African regionalization processes and policies.

African leaders, at the local, national, regional, and continental levels, must significantly increase public investments in biotechnology R&D. African universities and other institutions of higher education must: (1) create new skills; (2) produce scientific knowledge; (3) improve and upgrade R&D infrastructure; (4) reorient their missions to regional and continental economic priorities; and (5) provide more space and other resources for African women scientists to participate in R&D.

To improve commercialization and business capacity, Africa needs to: (1) foster R&D cooperative partnerships at the local, regional and international levels; (2) create policy instruments that enable business incubation and development; (3) develop functional market infrastructure for economic development; and (4) stress the role of technology in general and biotechnology in particular for SME development policy.

Africa must adopt the co-evolutionary approach where safety management goes hand in hand with the development of the technology itself. New stakeholder partnerships, awareness campaigns, and innovation competitions can be created to facilitate public understanding and education on issues of biotechnology.

The following mechanisms can be instituted to increase the available funding for biotechnology R&D in Africa: (1) substantially increased national R&D budgets; (2) special funding mechanisms, possibly Innovation Funds funded through a variety of means including "grand challenges approaches" similar to those adopted by the Gates Foundation; (3) specific funding mechanisms under development planning ministries; (4) distinct African funding schemes or facilities; (5) reformed tax law (i.e., foundation laws and industry-wide levies); and (6) national lotteries.

Strategic considerations

Africa needs to take strategic measures aimed at promoting the application of modern biotechnology to regional economic integration and trade. Such measures include fostering the emergence of regional innovation systems in which biotechnology-related "local innovation areas" play a key role. But doing so will entail a diversity of complementary measures that include upgrading regional capacities and forging international partnerships. Furthermore, funding such initiatives will involve adopting a wide range of approaches aimed at generating the necessary financial resources, including a "innovation funds". Existing funding sources such as international and regional development banks could also play a key role in helping in the commercialization of products from the biotechnology-related local innovation areas.

Regional economic communities should begin to determine potential opportunities for biotechnology specialization and foster regional networking of biotechnology centres for R&D related to this regional specialization. African Regional Innovation Communities should facilitate North-South and South-South collaborations as well as mobilize the knowledge network of its Diaspora for "thickening" emerging Regional Innovation Communities and Local Innovation Areas.

Governing Biotechnology

Africa must develop scientific capacity to assess biotechnology-related risks through regional and/or continental institutions or mechanisms so that all biotechnology policy is informed by science and not fear or scepticism. APB recommends the creation of an African Presidential Council of to oversee the implementation of AU recommendation related to science and innovation.

Africa's regulatory environments for biotechnology innovation are either nascent or hesitant. The evolution of regulatory systems has been largely influenced by international debates that are often not directly associated with the technological needs of the continent. The continent, through its regional economic communities, needs to adopt an evolutionary approach where regulatory systems develop hand in hand with technological opportunities and applications.

More specifically, emphasis should be put on maximizing the risks associated with new technologies while reducing their negative impacts. Equally important is a consideration of the long-term implications of non-adoption of emerging technologies. The essential point therefore is developing and harmonizing regional regulations governing issues such as regional integration, research and development, safety (covering field and clinical trials) and trade in biotechnology products and services.

There is a need to develop harmonized legislation and measures based on international, continental, and individual country good practices in the context of the emerging RECs. Development of such frameworks can lead to a co-evolution of regulatory frameworks and technology development. In addition to finalizing biosafety legislation, African countries need to make distinctions between transboundary movement, trade and release of GM products for R&D activities and those for seeds, food, or feed resolve within current policy, legal, and regulatory processes. African countries must strengthen the role of regulatory agencies to comprehensively address food standards and enforce those standards on issues of trade.

National food standards should be harmonized within regional regulatory mechanisms to allow for increased inter-state trade. Africa should develop a continental framework for IPR protection, ensuring that local biotechnological innovation is encouraged, global innovation is protected, and local communities are rewarded.

African countries should implement the SPS and TBT standards in African domestic legislation through regional and international collaboration. There should be the establishment/strengthening of desks at the REC secretariat staffed by experts capable of advising States on the international regulatory framework for Agricultural and manufactured products as provided for under the SPS, TBT Agreements and the Cartagena Protocol. AU/NEPAD should build and retain capacity guide and direct African States on the subject and also act as an advocacy group in dealings with the WTO and other relevant international institutions. The AU should consider establishing regional authorities or agenices under designated RECs to overseas the implementation of harmonized safety regulations.

Introduction

It is widely recognised that science, technology and innovation and their successful application are crucial for national survival, economic growth and sustainable development. Countries that are attaining higher levels of economic growth and human development are those that are investing in the development and application of science, technology and innovation. Those that ignore or give inadequate attention to science, technology and innovation on tend to be characterized by high levels of poverty, lack of economic competitiveness, and general inability to participate in the world trading system.

Economic growth and human development are proportional to a society's freedom to innovate. Historically, economic improvement has largely been a result of the application of knowledge in productive activities along with the restructuring of societal institutions. One of the major changes in recent development thinking is the realization that what separates developed and less developed countries is not just a gap in resources, but a gap in knowledge.[1] Therefore, development can be viewed as an interactive learning process that applies knowledge to the transformation of society and its value systems. This learning process requires the freedom to innovate, experiment, and innovate to promote a sustainable, ever-growing, and relevant knowledge base. The "freedom to innovate" values the openness to explore new knowledge, continuously reinvent current knowledge systems, and broaden access to education and learning to all citizens. Technological innovation as a process of learning is not only about economic transformation or technology transfer but more broadly a product of a society's proclivity to encourage, foster, and invest in learning in the most comprehensive sense.

Africa's "freedom to innovate" will require strategic investments and institutional adjustments in a number of activities representing the space and capabilities needed with which to innovate. Governance structures may need to be realigned to reflect a society's willingness to explore new forms of knowledge. Learning-based development might require alternative forms of international cooperation and interaction that stimulate innovative models of mentoring and learning. Universities, research institutes, and private sector firms may have to reinvent how they individually and collectively contribute to the generation, diffusion, transfer, and application of knowledge. Regulatory agencies and policy organizations may have to reconsider how their technology policies hinder or facilitate the learning process. And financial institutions might have to rethink the role that learning has in a global knowledge economy and may have to strategically adjust to provide the financial capability to with which a society can learn and innovate in increasingly competitive financial markets.

Applying knowledge through new technologies provides opportunities for improving economies and the well-being of people in developing countries. It offers avenues for increasing agricultural production, improving human health, stemming environmental degradation, enhancing industrialization and economic competitiveness. To benefit from the opportunities offered by the technological learning process, countries must formulate appropriate policies to build and use a range of critical capacities including human resources, infrastructure, financial resources and organizations.

This report is about the potential role of modern biotechnology in the transformation of African economies. Biotechnology refers to any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use. This report examines how a wide range of opportunities presented by the technology can be tapped by African countries. The report identifies and recommends strategic policies and programmes that will generate a critical mass of technological expertise in targeted areas that offer high economic growth potential. It focuses on how best to build the requisite capacity to harness and apply the technology to improve agricultural productivity and public health, increase industrial development and economic competitiveness, and promote environmental sustainability in Africa. The report also takes into account the importance of promoting the conservation and sustainable utilization of Africa's biodiversity.

The main message of this report is that regional economic integration initiatives in Africa should embody the building and accumulation of capacities to harness and govern modern biotechnology. Regional economic integration can be an institutional vehicle for mobilizing, sharing and using existing scientific and technological capacities, including human and financial resources as well as physical infrastructure for biotechnology R&D and innovation. The mobilization and building of critical capacities will need to focus on the creation of institutions and/or reorientation of existing ones to focus on regional priorities and programmes. It will also entail reviewing and adjusting national and regional policies and related legislation to provide an environment conducive for regional biotechnology R&D and innovation. (Box 1)

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Box 1: Background and mandate of the panel

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African governments have recognized the importance of regional cooperation to address possibilities and the range of issues associated with biotechnology and genetic modification. They have resolved to promote programmes that will "generate a critical mass of technological expertise in targeted areas that offer high growth potential" from biotechnology and the second is to harness biotechnology in order to develop Africa's rich biodiversity, improve agricultural productivity, and develop pharmaceutical products.

To address these issues, the AU and NEPAD established the High-Level African Panel on Modern Biotechnology (APB) to advise the AU, its Member States and its various organs, on current and emerging issues associated with the development and application of modern biotechnology. Its specific remit is to provide the AU and NEPAD with independent and strategic advice on developments in modern biotechnology and its implications for agriculture, health and the environment. It will focus on intra-regional and international issues of regulating the development and application of genetic modification and its products.

The APB will specifically consider:

1. The current and potential developments in modern biotechnology outlining the implications that may be associated with adoption and/or non-adoption of such technologies for regional economic and trade integration;
2. The specific priority areas that offer high potential for regional R&D, including aspects of risk assessment and management;
3. Whether and what aspects of the development and regulation of modern biotechnology should be harmonized into a regional/continental regulatory regime for shared R&D and technology management (this may include ways and means of integrating regulatory measures in existing Regional Economic Communities (RECs) and related trade arrangements);
4. The scientific capacity that will be needed to ensure the safe application and use of products derived from modern biotechnology, including human resources for research, laboratory testing, safety evaluation and enforcement;
5. Strategic ways of building Africa's scientific capacity for regionally oriented regulation and management of modern biotechnology; and
6. Ways of improving cooperation with other regions (particularly Asia and Latin America) of the world to effectively address trade, R&D and regulatory issues pertaining to modern biotechnology, including implementation of the Cartagena Protocol on Biosafety and the Codex Principles on risk analysis of food derived from modern biotechnology.

The panel shall make recommendations on the nature of regional institutional arrangements that are required to promote and sustain common regulatory approaches to the application and use of, and propose a strategy and policy on modern biotechnology.

In selecting the scope of coverage, this report should be read in conjunction with other important reports on science, technology, and innovation, such as InterAcademy Council, *Inventing a Better Future: A Strategy for Building Worldwide Capacities in Science and Technology* (Amsterdam, The Netherlands: InterAcademy Council, January 2004) and InterAcademy Council, *Realizing the Promise and Potential of African Agriculture* (Amsterdam, The Netherlands: InterAcademy Council, 2004).

This report is organised in three main parts. The first part lays out the conceptual framework and empirical basis for discussing the role of biotechnology in economic change and development. It emphasizes the importance of considering biotechnology as part of interdependent and converging technological systems of learning. The panel interpreted its mandate to cover measures that will promote the building of Africa's scientific and technological capacities to engage effectively with the safe development and application of biotechnology. It emphasizes that countries that are tapping the economic and human development potentials of biotechnology are those that are improving the overall conditions for the "freedom to innovate" by investing in scientific and technological development and creating national systems of innovation. It proposes the concept of a regional innovation system as a framework for promoting technological solutions to common or shared regional economic problems.

The second part of the report discusses regional biotechnology priorities and capacities. It shows that African countries have a wide range of new economic opportunities from biotechnology if they diversify their investments in R&D and applications to mining, industry, health, environment, and other areas in addition to agriculture. Barriers to entry into these areas or sectors are not necessarily many and can be reduced by building on existing infrastructure and other capacities. The report identifies those components or elements of scientific and technological capacities that exist and those required to enable African countries to realize high potential applications of biotechnology in these sectors or areas. A framework for regional innovation systems is proposed. Policy, legislative and institutional arrangements or conditions for building regional biotechnology innovation systems are also analysed in this section.

The last part is about strategic options that African countries have to collectively create regional biotechnology innovation systems. It offers policy ideas and related programmatic actions that may enable the African Union to promote specific regional capacity building and international cooperation to realize high potential of the safe development and application of biotechnology.

Chapter 1: Africa in the global economy

There has been increased political interest in finding ways to integrate Africa into the global economy as exemplified by the G-8 summit, the Blair Commission, and Millennium Summit and its follow-up. Following the G8 and EU summits in 2005 and various other recent commitments by developed countries, annual development aid is expected to increase by US$50 billion between now and 2010. This will make more resources available for all kinds of aid.[2] This current effort builds upon this momentum by analyzing the opportunities for biotechnology to contribute to economic development, wealth creation, and poverty reduction. A central message of this report is that Africa's future participation in the global economy requires learning how to innovate in economically-important, knowledge-intensive sectors like biotechnology.

Persistent and Emerging Challenges

Africa entered this millennium as the world's poorest continent. Most of the continent's economies are characterized by slow and declining economic growth, low and declining per capita incomes, and declining participation in the global trading system. African countries are predominantly primary low value commodity exporters. This strongly influences prices of their commodities on international markets.

In 2004, the continent registered growth of 4.6 percent, the highest in a decade. This was due to strong global recovery, high commodity prices and high oil production and prices (ECA, 2005). Good macroeconomic management, agricultural performance and improved political situations also contributed to the growth. Twelve African countries posted real output growth of 6 per cent or more in 2004, eight of which are either oil exporters (Chad, Equatorial Guinea, Angola, Libya and Sudan) or are recovering from a very low base (Ethiopia, Sierra Leone, Liberia, Mozambique, and the Democratic Republic of the Congo).[3] Only six countries realized growth rates of 7 percent or higher, namely Chad (39.4%), Equatorial Guinea (18.3%), Liberia (15%), Ethiopia (11.6%), Angola (11.5%) and Mozambique (8.3%).

The average GDP growth figures for the region mask considerable differences across countries, thereby painting a false picture of an Africa growing. North Africa is estimated to have grown at 4.8 per cent in 2004 which is close to the growth of 2003. In sub-Saharan Africa growth improved to 4.5 percent in 2004 from 3.9 per cent in 2003. The 2005 projections for both regions were estimated at 5.2 percent for North Africa and 4.8 percent for sub-Saharan Africa. At regional level, central Africa was the fastest growing in 2002 – 2004 with growth of 7.3 per cent in 2004, and in their decreasing order followed by east Africa (5.8%), North Africa (4.8%), West Africa (4.3%) and Southern Africa (3.5%).

Although the continent's GDP has improved over the years, the proportion of people living in absolute poverty is higher than in the 1980s and 1990s.[4] The recovery in economic growth in several African countries has not translated into higher income and more employment opportunities. Whereas African economies expanded by 3 per cent per annum, between 1990 and 2004, the proportion of its population classified as absolute poor increased by 2 percentage points every year. The weak response of poverty levels to economic growth is primarily because economic growth has been not only slower than expected but also grossly unequal. Consequently, at the 1.2% per capita annual income growth experienced since 2000, it will take Sub-Saharan Africa until 2012 just to restore average incomes to their 1980 levels.[5] The low labour absorption in the growth sectors is a second factor. Agriculture, the mainstay of African economies, is labour intensive but has grown too slowly to provide real employment and income security. Inequality in the distribution of economic opportunities hinders equitable economic expansion in Africa; there is limited opportunity for poor people to participate meaningfully in the economy, as either producers of goods and services or suppliers of labour.

One of the factors influencing poverty trends in Sub-Saharan Africa is the escalation and growth of conflicts. The number of countries faced with internal conflicts increased from 6 in 1980 to 14 in 2000. Conflicts have led to the destruction of economic, social and natural capitals of the countries. Real GDP per capita declined by at least 1 percent per year in conflict countries. "Widespread civil conflicts impose enormous costs, including on neighbouring countries. … Africa's conflicts … are driven by poverty, underdevelopment, and lack of economic diversification, as well as by political systems that marginalize large parts of the population. But conflicts perpetuate poverty, creating a vicious circle that can be reversed only through special development efforts…"[6]

Africa has the lowest human development and highest poverty indicators. Countries of the region have the highest illiteracy rates, and lowest primary education enrolment. In the 1990s per capita health expenditure in many African countries was a mere US$ 10, compared to at least US$ 1000 in the OECD countries. The rapid spread of HIV/AIDS has significantly reduced life expectancy in Africa. Life expectancy has declined drastically, especially in the Sub-Saharan Africa, 46.1 years, while remaining high in North Africa, 71.5 years. Adult HIV/AIDS prevalence rate in 2003 was 7.3 percent in Sub-Saharan Africa compared to 1.1 percent globally. In 2004, AIDS killed over two million people in sub-Saharan Africa with more than three million infected in that year alone. Three out of four of the young people living with HIV and AIDS are women in sub-Saharan Africa.[7] In Botswana and Swaziland adult HIV/AIDS prevalence was 37.3 percent and 38.8 percent, respectively, representing the highest rates per national population.

The devastating impact of HIV/AIDS is not only exacerbated by the increasing poverty levels but also a manifestation of the breakdown in African healthcare system. Health and education systems have been run down through years of neglect and there are huge deficits in doctors, nurses and teachers. Staying healthy is particularly expensive for the poor, with a third of their monthly expenditure going on malaria treatment alone. The number of men, women and children who suffer and who die from preventable disease in Africa is simply unacceptable. One in six children dies before their fifth birthday. Low cost interventions, such as vitamin A supplements, insecticide-treated nets, and oral rehydration, which could significantly reduce these deaths, are largely unavailable. One and a half million children die each year of vaccine-preventable illnesses.[8]

Disease burden and economic growth are intimately related. Healthy people are more productive and more likely to be able to take care of their children, benefit from education, and contribute to society. For example, de-worming children could reduce pupil absenteeism in schools by one quarter. The income levels of countries with severe malaria are a third of equivalent countries without malaria and grow 1.3 percent less per person annually. In Kenya, this would have translated as 50 percent greater incomes since 1970. Ensuring reliable access to and proper use of safe, effective and affordable diagnostic tests, medicines, vaccines, and reproductive health goods, such as condoms, are essential to health and a key function of effective health systems. It is estimated that nearly half of people in Africa do not have regular access to essential medicines. Many of the health challenges faced by Africa lack effective diagnostic, preventive or treatment options. Africa accounts for just 1.1 percent of the total value of the global pharmaceuticals market. This has meant that large pharmaceutical companies have not prioritised African health needs.[9]

Over 40 million children were estimated to be out of school in sub-Saharan Africa in 2005. Several countries remain at high risk of not achieving universal primary completion and gender equality by 2015; in Niger, Burkina Faso and Angola the expected number of years of formal schooling is less than five years on average, and over 60 per cent of children drop out of school in Chad, Equatorial Guinea, Guinea Bissau, Madagascar and Rwanda. Where more children are completing primary school, there is more demand for secondary or vocational education. Enrolment in higher education remain very low – most countries have gross enrolment rates below ten per cent, and in several cases less than one per cent, including Chad, Guinea-Bissau and Tanzania.[10]

However, expanding school enrolment across Africa is exerting pressure on the available teachers. Presently, most African countries have acute shortages of teachers, largely due to losses from the HIV pandemic and more teachers abandoning the profession. For example, Ghana has just a quarter of the teachers it requires, and Lesotho merely a fifth. In Namibia, only 40 per cent of teachers in rural schools in the north have teacher qualifications compared to 92 per cent in the capital. In Burkina Faso, the teacher shortage has been declared a 'national emergency' and people are being contracted from across the public sector to fill the immediate gap, whilst recruitment and training of teachers to a higher standard is undertaken. In Malawi, the introduction of free primary education in 1994 has led to an unprecedented demand for new teachers. Although there is little information on the impact of HIV and AIDS on teachers, what evidence does exist gives cause for concern – in Zambia mortality among teachers is reported to be 70 per cent higher than in the general population, although deaths are not attributed officially as AIDS related.[11]

Africa has a wealth of natural resources with the potential to drive economic growth and social development: land, minerals, biological diversity, wildlife, forests, fisheries and water, although these are unevenly distributed. In surveys, poor people consistently highlight the importance of the environment to well-being in terms of health, security, clean water, sanitation, safe energy, safe housing, food security and access to agricultural inputs. Africa's economies and people are vulnerable to environmental hazards such as droughts and floods, the frequency and extremity of which is likely to be increased by climate change. Additionally, sub-Saharan Africa is experiencing faster degradation of many environmental resources, important to poor people, than any other region. Problems include land degradation, desertification, biodiversity loss, deforestation, loss of arable and grazing land, declining soil productivity, pollution, and depletion of freshwater. Many of these are intertwined.[12]

Underlying causes of environmental problems include, amongst other things, rapid population growth and urbanisation, unsustainable agricultural expansion, over-exploitation of forests and ill-defined property rights. These pressures are increased by natural causes, such as highly variable rainfall, and wider pressures such as overall low economic growth, weak regulatory frameworks, the limited capacity of public institutions to respond, and collapses in governance associated with conflict. Such environmental challenges can have significant impacts on economic growth and social development. Deforestation removes key sources of food, fuel and medicines for rural poor people as well as degrading biodiversity and wildlife – part of Africa's comparative advantage for tourism and pharmaceuticals. More than 70 per cent of sub-Saharan Africa's population depends in large measure upon forests and woodlands for livelihoods and 60 per cent of Africa's energy demand is met by forests. The annual gross cost of environmental degradation in Ghana, including forest loss, soil erosion, health effects and land degradation, has been estimated to be US$127 million, or two percent of GDP.[13]

Good governance is the key to both growth and participation. Poor governance has been a negative influence on Africa's development since independence. Africa has suffered from governments that looted the resources of the state; that could not or would not deliver services to their people; that in many cases were predatory, corruptly extracting their countries' resources; that maintained control through violence and bribery; and that squandered or stole aid. Although Africa still lags far behind other regions, governance in Africa has improved significantly in recent years. Between the years 2000 and 2005, more than two-thirds of sub-Saharan Africa countries had multi-party elections, with a number of examples of peaceful, democratic changes of government. Not all elections involved transfers of power, but in terms of political freedoms, Africa has shown strong improvement in the last 20 years. Governance has improved on other fronts as well, including those more directly related to economic growth. Nevertheless, indicators of economic governance for the continent as a whole over the past few years show that sub-Saharan Africa continues to lag behind other regions, but these indicators are increasing at least as quickly in Africa as in any other region. Thus, Africa is working to create conditions where growth has a chance.[14]

Trade has been a key driver of growth over the last 50 years. As developed countries emerged from the devastation of the Second World War and the economic depression and protectionism of the 1930s, they began to open their markets. Trade among these countries expanded very rapidly, contributing to the strongest period of growth in their history. In the last twenty years, China and, now India, have seen rapid trade expansion contribute to their growth acceleration. Together with other countries, they have broken into new markets: 80 percent of exports from developing countries are now in manufacturing, whereas 20 years ago 70 percent were in primary commodities. The share of developing countries in world trade has risen strongly, with the share in manufacturing rising from 17 percent in 1990 to 27 percent in 20002. In stark contrast, the last three decades have seen stagnation in Africa. The composition of Africa's exports has essentially remained unchanged, and has contributed to a collapse in Africa's share of world trade, from around six percent in 1980 to two percent in 2002. These problems are reinforced by growth in other more dynamic regions which have managed to make major shifts into manufactures.

In their quest for greater economic prosperity and increased intra-Africa trade, African countries have attempted numerous initiatives towards regional economic integration. In the past four decades, a great number of regional cooperation and integration schemes have been adopted across Africa. There are currently more than twenty regional agreements that aim at promoting cooperation and economic integration. The African Development Bank notes that "[t]he fragmentation of Africa into many nation states with scant economic coherence led African leaders, following political independence, to embrace regional integration as a central element of their development strategy."[15] By engaging in regionalism, particularly economic integration, African countries wanted to break three main barriers to development: (a) small size of their individual economies; (b) dependence on import of high value or finished goods; and (c) dependence on a small range of low-value primary exports, mainly natural resources.

Regionalism in Africa also emerged out of the Pan African political aspiration for a continental identity and unity as well as the need to build hegemony that would intimidate the former colonial masters. The newly independent states wanted to ensure that the vestiges of the colonial past were dismantled or overcome. This aspiration was pronounced, to some extent realized, with the creation of the Organization of African Unity (OAU) in 1963. In 2001 the OAU was transformed into the African Union (AU). The Constitutive Act adopted in 2001 provides for greater political unity and economic integration and commits African countries to principles of democracy, protection of human rights, good governance, gender equality and people-centred development.

Following the creation of the OAU a plethora of regional treaties and institutions whose objectives are to promote regionalism emerged in the mid-1960s to the 1980s. These include the Customs and Economic Union of Central Africa (UDEAC) established in 1964, the East African Community (EAC), 1967-1977, which was revived in the early 1990s, Southern African Development Community (SADC),[16] the Economic Community of West African States (ECOWAS) in 1975, the Common Market for Eastern and Southern Africa (COMESA) in 1995,[17] and the Arab Maghreb Union (AMU) formed in 1989. The UN Economic Commission for Africa (ECA), established in April 1958, was instrumental in the establishment of the regional economic groupings of Africa. It gave the bodies an economic orientation. The ECA acted as a catalyst in the movements that stimulated governments to take practical measures of economic co-operation.

The main objectives of the regional groups were the eventual elimination of all tariffs and barriers between members, the establishment of a customs union, unified fiscal policy and co-ordinated regional policies in the transport, communication, energy and other infrastructural facilities. They aimed to open up national economies and benefit from the natural pull of geography and common culture and tastes. The experience and empirical evidence, however, show that Africa's traditional trade-focused model of regional integration has failed, not only in promoting African trade but also in encouraging economic growth.[18]

The overriding feature of most regional initiatives is the misconception that merely expanding markets for existing products would lead to economic growth. Countries thought that merely opening up borders would increase their trade. Since gains from trade have been minimal, at best, enthusiasm for regionalism has dissipated. African countries have ignored the importance of developing and strengthening domestic capabilities to trade, and overlooked the importance of trade facilitation initiatives such as the development of infrastructure and institutions. Consequently, the bigger markets created by regional integration have neither encouraged innovation nor nurtured the potential economies of scale created by the development of infrastructure.[19]

One of the central messages emerging from the assessment of Africa's status in the global economy is the need for Africa to emphasise building the capacity to solve its own problems. Every problem enumerated has one or more solutions in the application of science, technology and innovation. The focus should be on economic growth as a critical basis for addressing poverty, especially the role of technology and innovation. A new economic vision for African countries – articulated at the highest level of government – should focus on the role of knowledge as a basis for economic transformation. Doing so will entail placing policy emphasis on emerging opportunities such as renewing infrastructure, building human capabilities, stimulating business development, and increasing participation in the global economy.[20] These areas should provide a firm foundation upon which to base international partnerships. Africa should therefore make the transition from short-term relief-oriented to long-term economic development based on building competence at all levels of science.[21]

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The Potential Role of Technology in Development

At least three key factors have contributed to the rapid economic transformation of emerging economies. First, these countries invested heavily in basic infrastructure, including roads, schools, water, sanitation, irrigation, health centres, telecommunications and energy. The investments served as a foundation for technological learning. Second, they nurtured the development of small and medium-sized enterprises. Building these enterprises requires developing local operational, repair and maintenance expertise, and a pool of local technicians. Third, government supported, funded and nurtured higher education institutions, as well as academies of engineering and technological sciences, professional engineering and technological associations, and industrial and trade associations.[22]

The emphasis on knowledge should be guided by the view that economic transformation is a process of continuous improvement of productive activities, enacted through business enterprises. In other words, development strategy should target *continuous improvement* aimed at enhancing performance, starting with critical fields such as agriculture. This improvement indicates a society's capacity to adapt to change through learning.[23] It is through continuous improvement that nations transform their economies and achieve higher levels of performance. Using this framework, with government functioning as a facilitator for social learning, business enterprises will become the locus of learning, and knowledge will be the currency of change. The role of science and technological innovation in economic change and sustainable development is receiving considerable attention at national, regional and international levels. There is ample evidence that economic advances in the developed and newly industrializing countries are results of technological and organizational innovations.[24] The key to their success was their focus on improving skills in solving existing and new problems, putting a premium on learning. One of the most elegant aspects of a learner's strategy is that every generation receives a legacy of knowledge that it can harness for its own advantage. Every generation blends the new and the old and thereby charts its own development path, making debates about innovation and tradition irrelevant.

Globally, science and technology are recognised as drivers of increased wealth and continuously improving standards of living. Analyses from a variety of perspectives lead to the same conclusion. Since the beginning of the Industrial Revolution (circa 1870), scientifically and technologically advanced countries have become continuously wealthier, and their rates of growth have not slowed significantly over time.[25] These countries have succeeded by reinvesting a growing percentage of their gross domestic product in further advancement of research. Each year, the 29 member countries of the Organisation for Economic Co-operation and Development altogether spend about 1.5 times more on research and development than the entire economic output of sub-Saharan Africa.[26] Ambitious developing countries have followed suit, increasing research capacity and skills development in a variety of science and technology disciplines. Knowledge creation through research, however, is only one part of the story.

Translation of research into new, more efficient modes of production has brought dramatic benefits. Technological innovation is associated with turning scientific knowledge into products and processes. It is about putting new technologies on the market and incrementally modifying and adjusting them to respond to socio-economic conditions.[27] For example, agricultural productivity has grown sharply: world food production doubled between 1961 and 1998 with virtually no increase in land under cultivation.[28] From 1980 to 1996, trade in high-tech manufactured goods grew at double the rate of resource-based goods.[29] Some of the East Asian countries that capitalised on these opportunities have transformed themselves into middle- or even high-income economies.[30]

Technological innovation often emerges through institutional and organizational changes or adjustments such as the creation of new enterprises, modification of production systems, and reforms of policies.[31] Understanding the evolution of new technologies in socio-economic systems is crucial for making technology choices and ensuring that investments are directed to areas that have high potential to create wealth and promote sustainable development. We identify the main components of knowledge-driven economic development in sections that follow. These include the critical role of infrastructure, human capabilities, business development, and technological readiness.

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Potential Role of Biotechnology in Africa

Biotechnology has been the subject of public policy aspirations for the last two decades. Agenda 21, the work programme adopted by the 1992 United Nations Conference on Environment and Development, stated that biotechnology "promises to make a significant contribution in enabling the development of, for example, better health care, enhanced food security through sustainable agricultural practices, improved supplies of potable water, more efficient industrial development processes for transforming raw materials, support for sustainable methods of aforestation and reforestation, and detoxification of hazardous wastes". Biotechnology has also been used to reclaim waste land through the use of micro-organisms and plants that remove and/or degrade toxic compounds. Some firms have incorporated biotechnology techniques in their production to decrease energy and water consumption, improve productivity and reduce the number of processing steps. All these actions could lead to an improved environment, sustainable use of resources and increased productivity.[32]

Biotechnology-related applications and products have penetrated all sectors of the global economy. The technology has begun to overcome the bottlenecks that, in the last century, favoured chemical substitutes against biological ones. As the knowledge base of biotechnology consolidates, the number of platforms that will depend on it will multiply to generate new fields. Despite these developments, biotechnology does not seem to have taken root in African countries and the goals have not been attained. Food insecurity, disease and poverty still ravage a huge section of the human population, mainly in developing countries.[33]

African countries face the challenge of adding value to their natural raw commodities. Biotechnology offers new opportunities for countries to make the transition from producing raw materials to processed high value industrial products. Whereas the benefits of discoveries in the life sciences are known in the fields of medicine and agriculture, commercial opportunities in mining biotech are not as well understood in most African countries. The gains from biotechnology will not automatically accrue to developing countries, particularly those of Africa. Those countries and their institutions, particularly industrial firms that invest early enough in research and technological innovation are the ones most likely to exploit economic advantages offered by the technology. It is not necessarily large firms that are poised to take market advantages and enlarge industrial inequalities. Countries such as India, Cuba and China have demonstrated that small enterprises can acquire technological and market niches in modern biotechnology. This is particularly so in non-agricultural and pharmaceutical areas where a high concentration of large firms already exists.

The most promising areas for African countries are likely to be in adding value to minerals, forest products and related products.[34] Another area of promise is the bio-energy sector, especially for countries without fossil fuels. The development and adoption of biofuels can save Africa significant foreign exchange currently used in oil imports. Biotechnology presents new opportunities to transform these areas industrially, thereby enabling African countries to put on the international markets new value added products.

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Regional Innovation Communities

To apply biotechnology to the African context, there is a need to create mechanisms of technological learning that are regional in character Such mechanisms for learning are framed discussions related to innovations systems. Innovation systems are thought of having three actors, i.e. public research institutes, academia, and industry. In addition, there are governments at different levels (i.e. the central, regional, provincial, municipal, etc) play the role of coordinator amongst actors in terms of their policy instruments, visions and perspectives for the future. A systems approach is emphasized because technological innovation nowadays requires lots of resources and accompanies very high level of risks, so that any single innovation actor could not generate and exploit them effectively. In order to create an environment conducive for technological innovation, innovation actors should cooperate closely with each other based on a strong level of trust, and governments should actively promote and activate the trust and interaction between such innovation actors. One among the good ways to enhance trust among innovation actors is to apply such an innovation systems approach.[35]

African regional innovations communities must be defined as coterminous with the emerging Regional economic Communities (RECs). The integration of S&T considerations into the regional agreements is also recognition that the individual African economies are unable to marshal adequate scientific and technological resources for development. Many African countries have peripheral national innovation systems characterized by "institutional thinness" and inadequate human, financial, and social capital. Thus, economies of scale would dictate that such countries combine their resources for greater effectiveness. Africa, therefore, has a wide range of regional instruments—policies, programs, protocols and treaties—that articulate the importance of S&T cooperation. The impact of bigger markets on technological innovation, and the economies of scale and the diffusion of technical skills arising from infrastructure development are some of the most important gains Africa could make from regional integration.[36] The emergence of regional innovation communities, marshalling the S&T resources and capacities of individual African countries, can be critical drivers for the REC development.

Long-term process of biotechnology development in Africa should go hand-in-hand with the creation of regional economies. African countries should (1) facilitate the process of regional integration; and (2) foster technological innovation as a force for promoting regional integration and trade.

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Local Innovation Areas

Central to the regional innovation communities, corresponding to the emerging RECs, is the development of local innovation area, which serve as loci of technological activity where there are concentration of regional R&D institutions, firms, and universities. Local innovation

centres are where competitive advantage resides in the locations of business units, outside of businesses or associated industries. They can be defined as "geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions (for example, universities, standards agencies, and trade associations) in particular fields that compete but also cooperate. Critical masses of unusual competitive success in particular business areas, … [they] are a striking feature of virtually every national, regional, state, and even metropolitan economy..."[37]
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Box 1: Local Biotechnology Innovation Centre in Turku, Finland
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Turku is the second biggest concentration of biotechnology related activities in Finland, a European leader in biotechnology.[38] Modern biotechnology developments in Finland over the past twenty years have been catalyzed by national innovation policies, strong public investments (i.e. Academy of Finland, the National Technology Agency (Tekes), and the Finnish National Fund for Research and Development), and private-sector contributions.[39]

The tight-knit network of universities and service companies involved in drug development, and the recent flood increase of smaller companies in the last decade, is the result of technological and knowledge roots going back as far as the half a century ago. The first drug companies (Leiras and Farmos) that were created in the 1940s established a tradition of cooperation with some university groups and departments to ensure the availability of professional employees from technology centre. With the scientific knowledge base in serious development since the 1960s or 70s, the high level of biotechnology research became a critical input for the growth of Turku's biotechnology industry.[40]

Another important factor for the new biotech start-ups was the strong academic links to the U.S. The postdoctoral training of many PhDs and doctors from Turku in the U.S. during the molecular biology revolution in the 1970's provided them the opportunity of witnessing firsthand the birth of commercialized biotechnology and the ways in which academics intermingled with the business of medicinal biotech. A few lead researchers subsequently came back to Turku and were instrumental in setting up the Centre for Biotechnology and a few promising start-ups.[41]

Another key event in the biotechnology trajectory of Turku was the construction of BioCity, the first biotechnology centre building in the city. It not only introduced the biotechnology centre as an innovative environment for R&D, but the conceptualization and construction of the building facilitated a new kind of collaboration between the city administration, the universities and various commercial actors.[42] In addition to the above-mentioned developments, Table 1 below describes some of the factors that were instrumental in the birth and upgrading of Turku's biotechnology innovation centre.

Local innovation areas capture important linkages, complementarities, synergies, and spillovers of technology, skills, information, marketing, and customer needs across multiple firms and industries. Local innovation areas increase firm and industry productivity, increase firm and industry innovative capacity and productivity growth, and incubate new businesses that buttress innovation and expand the centre. Local innovation areas play an integral role in the competitive transitions from imitation to innovation and low investments to high investments (in physical assets and intangibles like skills and technology). They also promote productivity through access to specialized inputs and employees, access to information, complementarities, access to institutions and public goods, and incentives and performance measurement.[43]

Although local innovation areas are seen in both developed and developing nations, those in developing nations typically suffer from a lack of depth and rely primarily on foreign components, services, and technology. These also have fewer participants, limited communication, and undeveloped linkages between existing firms and institutions. The absence of infrastructure and institutions in outlying areas, coupled with the almost total lack of available suppliers, influences the tendency of economic activity and local innovation centre presence to concentrate around large capital cities. Therefore, the successful deepening and broadening of local innovation centres into "well-functioning" local innovation areas is integral to successful economic development and movement towards a more advanced economy.[44]

Table 1: Factors contributing to the development of Turku's Biotechnology Innovation Centre[45]

Factor	Description
Strong science base	In the recent international evaluation the science base in Turku was found of high level.
Entrepreneurial culture	A lot of new companies have been born. The general culture is still not very entrepreneurial.
Growing company base	Company base has grown rapidly in many fields in the last part of the 1990's.
Ability to attract key staff	So far the local and other Finnish universities have been able to provide staff from inside Finland. According to many companies a key problem in the future, especially for foreigners, is that Turku is too small and not very attractive.
Availability of finance	Lack of MNCs and international VC is a problem. Domestic VC (especially public) has substituted international VC. Recently VC money has been tighter and there have been big problems in attracting financing. Remote location and the lack of Finnish private VC are also challenges.
Premises and infrastructure	Generally the infrastructure for both research and business is very good. Public sector (especially the City of Turku) has been very active in supporting building new infrastructure recently. This has been important as the university basic funding has been very tight at the same time.
Business support services and large companies in related industries	The larger companies do not use that much local services but have international partners. Many specialized services are in Helsinki and abroad. There are some good local services but the number is still quite small.
Skilled workforce	A Good level of education in the local universities has so far been an adequate source for labor. The long tradition in pharmaceuticals and diagnostics provides experienced people though not enough for specialized jobs. Especially lack of business expertise related to biotechnology and internationalization is seen as a problem. Small city size has a negative impact on the general functionality of the labor market.
Effective networks	Local networks are working effectively. These networks have also been born voluntarily around important issues, which have made them efficient. Global networks are quite wide and also important especially for research but also for commercialization.
Supportive policy environment	National policy has been very important in providing financing both for research and commercial development. Local policy has been more important recently in supporting infrastructure. University policy and structures have not been not hindering but not helping either.

Successful local innovation areas development initiatives have some common characteristics: (1) a shared understanding of the role of local innovation area in problem-solving; (2) a focus on removing obstacles and easing constraints; (3) a structure that embraces all local innovation areas in a nation, state, or region; (4) appropriate local innovation centre boundaries; (5) wide involvement of local innovation centre participants and associated institutions; (6) private-sector leadership; (7) close attention to personal relationships; (8) a bias towards action; and (9) institutionalization. A long-term process for local innovation centre upgrading must be established, involving all key constituencies and accompanying institutions and rising above the politics of any particular government administration.

The government's role in the local innovation area upgrading program should involve all levels of government. These local innovation centre development initiatives must nurture competitive advantage and specialization, rather than attempt to imitate exactly what is present in other locations. This focus on local differences and sources of uniqueness gives a local innovation centre its comparative advantages. The local innovation centre thus offers a complementary method of understanding a nation or region's economy, organizing economic development thinking and practice, and setting the appropriate public policy for wealth creation.[46]

Local innovation areas hold the promise of creating competitive, biotechnology-driven African economies that benefit from spatial concentrations of regional innovation actors (universities, firms, and research institutes) Countries and RECs should (1) identify biotechnology-related fields of local relevance; and (2) facilitate local innovation centre upgrading initiatives for economic development.

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Strengthening International Cooperation

Cooperation with other regions of the world offers Africa many opportunities to build regional biotechnology innovation systems. Such cooperation will take different forms based on specific African needs and R&D activities in the other regions.

South-South collaboration between companies in developing countries can also create new opportunities for entrepreneurs. Cuba's Heber Biotech, a semi-private company, has helped commercialize Cuba's biotechnology products. By 1998 Heber Biotech was recording about $290 million annually in sales of hepatitis B vaccines and pharmaceuticals in 34 countries. Now the company is entering into partnerships with other developing countries. In 2001 it established a joint marketing venture with Kee Pharmaceuticals of India. The company's new division, Kee Biogenetics, has launched India's first recombinant DNA product, streptokinase, capable of dissolving coronary clots and preventing heart attacks. The resulting drug, Cardiostrep, is owned by Heber Biotech. The company aims to use special pricing to access the $11 million Indian market.

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Box 2: Brazil, India, and South Africa are working together on nanotechnology and efforts to prevent and treat HIV/AIDS

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Science ministers from Brazil, India, and South Africa have been working together to identify areas for trilateral cooperation over nanotechnology and efforts to prevent and treat HIV/AIDS. Their first meeting was held in October 2004, as part of the India-Brazil-South Africa trilateral commission. The meeting followed a meeting of the three countries' foreign ministers in Brasilia in 2003. That session identified science, technology, and innovation as one of the key areas for trilateral cooperation.

The partnership was inspired by the low level of investment in research on tropical challenges. This is the first major effort to promote cooperation with a focus on emerging technologies. It is likely that the collaboration will inspire other countries to want to join the group or seek to benefit from the results of the alliance. It is possible that industrial countries will seek to be party to this important initiative, at least indirectly.

Specific initiatives to help small and medium-size enterprises in biotechnology are a recent and promising development in some countries. The eGoli BIO life sciences incubator, launched in 2003, is a business incubator that aims to nurture small, medium, and micro-sized biotechnology enterprises for commercialization. eGoli BIO seeks to act as a "development conduit for the commercialization of life sciences research, products, services and technology platforms" in South Africa. The company works closely with the Biotechnology Partnership for Development, it is charged with stimulating economic development, contributing to job creation, and building world-class skills and technology platforms to sustain and continue development.

Numerous efforts have been made, especially through the United Nations, to promote South-South cooperation (Box 2). In additional to regional cooperation arrangements, opportunities for cooperation exist with Brazil, China, India, Malaysia, and Mexico, which could play important roles as technology mentors for their developed countries. Such alliances should be based on technological needs and capabilities and not on ideological grounds similar to those that that characterized the Cold War era.

There is great potential in developing North-South and South-South collaborations supporting biotechnology R&D and capacity-building in African regional innovation communities and local innovation areas. Countries and emerging RECs should identify ways of improving cooperation with other regions (particularly Asia and Latin America) of the world to effectively address issues pertaining to modern biotechnology.

Chapter 2: Mapping Global Developments in Biotechnology

Biotechnology refers to any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use. Biotechnology can serve as a critical tool in Africa's development through value-added improvements to the products targeted for the export and domestic economies. Africa's ability to research, develop, harness, and innovate upon biotechnological products and processes will in part determine its propensity to catalyze the long-term process of economic transformation and societal uplift.

This chapter presents current and potential developments in modern biotechnology and outlines those implications that may be associated with adoption and/or non-adoption of such technologies for regional economic and trade development. It explores how increasing technological convergence presents Africa with new economic opportunities and threats.

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Global scientific and technological trends

Most developing country governments acknowledge that science, technology, and innovation are important tools for development. But most countries still distinguish between science, technology, and innovation policies designed to focus on the generation of new knowledge through support for R&D and industrial policies that emphasize building manufacturing capabilities. Convergence of the two approaches would focus attention on the use of existing technologies while building a foundation for long-term R&D activities.

This approach requires that we pay increased attention to existing technologies, especially platform (generic) technologies that have broad applications for or influence the economy. Until recently, countries relied on investment in specific industries (textiles, automobile manufacturing, and chemicals) with broad linkages in the productive sector to stimulate economic growth. Policy attention has now turned to ICT, biotechnology, nanotechnology, and new materials as sets of platform technologies whose combined impact will have profound implications for long-term economic transformation.

Biotechnology has emerged as one of the tools that can be used to address development issues. The realization of this potential, however, depends on a diverse set of policy instruments aimed at translating scientific discoveries into goods and services. Modern biotechnology has opened a wide range of possibilities of identifying, isolating, selecting and transferring genes from one organism into another. Essentially, "genetic information contained in a gene of a cell of one organism is isolated, taken out of that organism, and placed in the chromosome of a cell (or cells) of another organism. The resulting DNA in the recipient cell contains both its own original, naturally occurring genes and the new gene. …the characteristic encoded in the foreign gene will be manifested, or "expressed", in the recipient cell…"[47] These developments have irreversibly changed agricultural, medical, environmental and industrial research and related innovations.

The 1990s witnessed a new wave of scientific advances in biotechnology. The mapping and sequencing of the human genome have given rise to a new scientific enterprise-- functional genomics. Functional genomics involves the use of the knowledge that converts the molecular information into an understanding of gene functions and effects: how and why genes behave in certain species and under specific conditions. Functional genomics also entails research on the protein function (proteomics) or the whole metabolism (metabolomics) of an organism. It has granted scientists an unprecedented access to the molecules of life. Through it massive amounts of biological information can be converted into electronic form, linking life sciences to information sciences. The science of functional genomics and associated techniques enable scientists to simultaneously analyse the identity and function of tens of thousands of different genes. It has considerably increased the speed and scale with which genomes of organisms are sequenced and functionally analysed.

Advances in modern biotechnology are to a large extent related to increasing technological convergence: two or more technological systems converging to enlarge their applicability and pervasiveness. An example of technological convergence is bioinformatics - biotechnology converging with information and communications technologies to expand the applicability of biological sciences and techniques. Increasingly, biotechnology development and applications rely on the existence of other technological systems and infrastructure. They are dependent on the National Innovation System (NIS) and thus discussions on the technology and its economic impacts must be cast in the broader context of scientific and technological development.

While most of the international debate has so far been directed to developments and applications in agriculture, there are other sectors or areas where biotechnology offers increasing economic potential for Africa. For example, in health and medicine, the application of functional genomics is enabling scientists and companies to identify genes that are linked to particular diseases. They are able to develop genetic tests that can facilitate prevention of certain illnesses. This science has also advanced drug development in very profound ways. Combined with advances in imaging technology and sensors, medical practitioners will be able to use genomic approaches to diagnose many neoplastic diseases and offer early treatment. The completion of the mapping of the genomes of malaria parasite, the bacteria, *T. parva*, and many other parasitic organisms will help the development of vaccines and other control measures for many of diseases in developing countries.

In general, a wide range of R&D activities are maturing at a remarkably fast rate. The convergence of biotechnological techniques, materials and devices will transform the way a host of health, industrial, food and environmental products are designed and used. These developments create the bioeconomy—covering a broad range of economic activities, each benefiting from new discoveries, related services and products arising from the application of life sciences.

There is a natural convergence of S&T policies from various technological disciplines, especially biotechnology, and industrial policies aimed at building manufacturing capacity as a national economic development strategy. Countries must focus increased policy attention on the use of existing technologies like biotechnology, which potentially have broad implications for the economy, while building a foundation for long-term R&D activities.

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Sectoral Discussions on Biotechnology

Biotechnology is a name given not to one technique or application but to a number of techniques which can be applied in a variety of sectors such as agriculture, health, industry and environmental management.

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Agricultural Biotechnology

No other economic sector has witnessed rapid developments and applications of modern biotechnology as agriculture. The global area of approved biotech crops rose to 90 million hectares in 2005 from 81 million hectares in 2004, representing an annual growth rate of 11 percent. The number of countries growing biotech crops increased from 17 in 2004 to 21 in 2005 by 8.5 million farmers. Of the farmers that grew biotech crops in 2005, 90% were resource-poor from developing countries (James, 2005).

The countries that grew biotech crops in 2005 comprise eleven developing and ten developed, namely, in order of crop area, USA, Argentina, Brazil, Canada, China, Paraguay, India, South Africa, Uruguay, Australia, Mexico, Romania, the Philippines, Spain, Colombia, Iran, Honduras, Portugal, Germany, France and Czech Republic. The largest increase in a country of biotech crop area was in Brazil by 4.4 million hectares, followed by US (2.2 million hectares), Argentina (0.9 million hectares) and India (0.8 million hectares). In 2005, herbicide tolerance continued to be the predominant trait of the biotech crops grown (71% of the global crop area) in soybean, maize, canola and cotton, *Bt* crops were planted on 18% of the area while 11 % was for crops with stacked genes.[48]

These developments in agricultural biotechnology and particularly the commercialisation of genetically modified products are increasingly influencing international agricultural trade patterns. In 2005, the global market value of biotech crops was US$5.25 billion comprising 15% of the global crop protection market (US$34.02 million) and 18% of the seed market (~US$30 billion). The biotech soybean market represented 46% of the global crop market in 2005. The cumulative global biotech crop market for the period 1996-2005 is estimated at US$29.3 billion.

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Forestry biotechnology

Another area of growing biotechnology applications is forestry. Forest biotechnology research and application is growing in scope. The Food and Agriculture Organization has identified forest biotechnology R&D in 76 countries.[49] These R&D efforts cover a wide range of aspects. Biochemical and molecular markers play a significant role in many forest biotechnology activities, and marker development for trees has closely followed that for humans and agricultural crops. Marker-assisted selection and genomics are the next wave of biotechnology applications which will mostly be used by paper making industries (table 2). Currently, expressed sequence tags and single nucleotide polymorphisms represent the most active area of marker development in forestry. Work with these markers is being driven by large genomic and association genetics projects.

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Table 2: Proportion of global forestry biotechnology activities by major categories[50]

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Forestry biotechnology activity	Percent
Micropropagation	34
Marker development and diversity studies	26
Mapping, marker assisted selection, and genomics	21
Gene modification	19

There are more than 210 field trials of genetically modified trees in 16 countries worldwide with majority of these being in the USA. The majority of the gene modifications are investigating gene stability, expression or basic biological questions which include functional genomics or tissue culture. The other modifications are for herbicide tolerance (13%), biotic tolerance (12%), wood chemistry (9%) and fertility related issues (6%). The most important tree genera that have been modified include *Poplus* (51%), *Pinus* (23%), *Liquidambar* (11%) and *Eucalyptus* (7%). As of 2004, commercial release of GM trees had only been carried out in China.[51]

Health and medical biotechnology

The medical biotechnology sector has developed over the last decades at an unprecedented speed and it is clear that human-health-related biotechnologies are already influencing and will continue greatly to influence the provision of medical care, irrespective of whether it is supplied within a private or public sector framework. New and emerging biotechnologies offer many opportunities that are likely to change the way society understands and treats disease. As countries make major investments in biotechnology-related innovation, they need to develop accompanying policy tools to ensure that the benefits of R&D are harnessed to improve the health of citizens and to create systems that facilitate bio-innovation.

Biotechnology has made significant strides in the health sector in both developed and developing countries and the field is less controversial than agricultural biotechnology. Application of intensive science and technology solutions to address health challenges in developing countries is required just like in the developed countries. The diseases of poverty, malaria, TB and HIV/AIDS greatly affect the economic development of African countries due to their effect in rendering the sick and their wards economically unproductive and the amount of resources spent by African countries on these diseases. Biotechnology tools such as genomics afford promise of shortening the time required to develop a number of drugs for these diseases.

Several African countries have programmes dedicated to biotechnology R&D and applications to human health. Health biotechnology research and application initiatives are found in Egypt, Kenya, Tanzania, South Africa and Uganda. In Tanzania for example, the application of molecular markers for mapping of disease resistance in *Plasmodium falciparum* is being carried out at the Ifakara Health Research and Development Centre. This is a collaborative research programme being carried out in six African countries (Ghana, Nigeria, Malawi, Mali, Tanzania, and Uganda) and is jointly coordinated by UNDP, World Bank and WHO. Another activity being carried out is the search for biologically active substances, which could have potential pharmaceutical uses. This is intensively being carried out at Tanzania's Muhimbili University College of Health Sciences (MUCHS), particularly at the Institute of Traditional Medicine in collaboration with the Faculty of Pharmacy and at the University of Dar-es-Salaam (Department of Chemistry).

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Box 3: Niprisan® Production in Nigeria

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The National Institute for Pharmaceutical Research and Development, Abuja, Nigeria conducted scientific and clinical investigations on the use of standardized herbal extract for treating sickle-cell disorder. The herbal medicine called Niprisan showed very good efficacy and safety profiles. It was subsequently licensed to an American company for multiplication. The company has established facilities in Abuja for global production of Niprisan. The product was scheduled for official launching in May 2006 by the President of Nigeria. The experience with Niprisan shows that the natural multi-component preparation is necessary for the efficacy and safety of herbal medicines.[52]

South Africa has been actively involved in the development of vaccines for HIV/AIDS and other diseases of poverty. The country is the first in Africa to execute multiple HIV/AIDS vaccine trials and in the world to engage in a trial on preventative vaccine against the HIV-1 subtype. A total of six potential novel candidate vaccines were reported to be under evaluation at the University of Cape Town and University of Stellenbosch in 2004. Vaccine development has been carried out through international public-private partnership involving South African and international partners.[53] South Africa has also employed indigenous knowledge in its health biotechnology research and development where hunger-suppressing steroidal glycoside has been isolated from a cactus *Hoodia gordonii* and patented. The cactus has been traditionally used by the San people who live in semi-desert of the country to suppress hunger and thirst during long bouts of hunting.

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Box 4: Production of medical Diagnostic Kits in Kenya

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The Kenya Medical Research Institute (KEMRI) has the infrastructure and adequate personnel to handle R&D in medical biotechnology. KEMRI, in partnership with other organizations, has developed the Hepcell, a diagnostic kit for detecting human Hepatitis B surface antigen. The product, already in use in all district and provincial hospitals in Kenya, was developed to provide an effective cheap diagnostic kit.

The Japan International Cooperation Agency (JICA) is supporting KEMRI in commercial production of the Hepcell kit. The major outlets of the kit are the public hospitals through the National Public Health Laboratory Services. The institute also collaborated with JICA to develop a diagnostic kit known as Particle Agglutination (PA), a simple HIV test kit. The kit has advantages over the other kits because its reagents are produced domestically, do not require electric power and, its results can be viewed by the naked eye. A joint research on malaria vaccine is ongoing in collaboration with the Wellcome Trust Laboratories.

KEMRI has initiated the establishment of production and commercial units for its products, which could be a source of the much-needed funds to sustain the institutes' R&D activities. KEMRI has up to Level 3 biosafety laboratories, the establishment of which has enabled the institute to characterize the HIV virus and provide a basis for vaccine development using local virus definitions. The institute handles biosafety through the application of good laboratory practices (GLP) and application of Good Clinical Practices (GCP). As such, it conducts clinical tests for pharmaceutical company products on contract basis.[54]

Egypt has posted success in the application of biotechnology to address health problems. Products for treating such conditions as cardiovascular, cancer, anaemia and diabetes have been developed and commercialized by local companies (table 3).

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Table 3: Examples of Egyptian health biotechnology products[55]

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Sector	Type	Product name	Application
Therapeutics	Recombinant human streptokinase	Sedonase Streptokinase	Cardiovascular
	Recombinant human interferon α-2b	Intron A Reiferon Natuferon Ismaferon	Cancer
	Recombinant human erythropoietin α	Erypoietin Epoetin Pronivel	Anaemia
	Recombinant human insulin	Mixulin-H 30/70 Insulin H Human insulin-Mix Danofran	Diabetes

Industrial biotechnology

Advances in biotechnology related fields such as genomics, genetic engineering, chemical engineering and cell technology are transforming the industrial process and management landscape.[56] These advances are having particularly far-reaching impacts on the chemical industry. Industrial applications of modern biotechnology are emerging as a spin-off from developments in other fields such as the pharmaceutical sector. Industrial biotechnology covers two areas. The first is the use of renewable raw materials to replace fossil fuels. The other is the use of biological systems such as enzymes to replace conventional non-biological methods.

One of the main advantages of industrial biotechnology is the prospect for controlled production of biological catalysts. Biocatalysts offer greater potential for cleaner industrial production. They generate fewer by-products and can be used in waste treatment. In more industrial sectors, companies are becoming aware of the importance of sustainable development and of the great potential of biotechnology. Biotechnology can help improve the environmental friendliness of industrial activities and lower both capital expenditure and operating costs. It can also help reduce raw material and energy inputs and waste.

Industrial biotechnology holds great potential to revamp chemicals and industrial manufacturing. Industrial biotechnology is driven by new varieties of enzymes, where genetically modified enzymes are being produced for use in the manufacturing industries such as chemicals, textiles and paper. Apart from the economic benefits derived from industrial biotechnology, the technology mitigates environmental impacts because manufacturing processes based on industrial biotechnology products often use less energy and generate less waste. The technologies leverage biodiversity resources to provide unique raw materials.

Riese estimates that about 5% of industrial chemicals are bio-based including alcohols, amino acids, vitamins, pharmaceuticals and special chemicals, and predicts that this may increase to 10-20% by 2010.[57] The world's first bio-refinery, Iogen of Canada, is converting wheat straw into ethanol for blending with gasoline which will result in considerable reduction in production of fuel. White biotechnology is a growing industrial base in Europe where genetically modified organisms are used for the production of enzymes and vitamins. Enzymes are used in the pulp and paper, textile and leather industries.

In 21 OECD case studies, successful acceptance by industry of bioprocesses was associated with decreased adverse environmental impact and increased cost efficiency. The biotech-process was environmentally friendlier than the processes they replaced.[58] Advances in biotechnology and chemistry are making it economically and environmentally attractive to manufacture fuels, chemicals and materials from biomass. At present, more than 90% of fuels, chemicals and plastics are derived from oil and natural gas. Industry is beginning to use biomass as a feedstock to produce bio products that can complement petrochemical products and extend the life of existing petroleum resources.

Biomining is another biotech application that is being developed. Over 25% of all copper worldwide is produced through bio processing. The technology is also used to extract gold from very low grade, sulphuric gold ores, which was thought to be worthless. Efforts are underway to engineer bacterial strains that can stand up to heavy metals such as mercury, cadmium, and arsenic which are known to poison microbes and slow the bio processing.

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Environmental biotechnology

There is enormous potential for using biotechnology to reduce human impact on the environment. Environmental applications or uses are still being developed, but include bioremediation (treating contaminated soils), bio processing (cleaner production, waste management, bio monitoring and immunocontraceptives for feral pests). There is also growing acceptance of new applications for biotechnology in mining. This coincides with the rising demand world-wide for natural resources. This coupled with the pressure to introduce environmentally-friendly mineral extraction and processing technologies, as well as the subsequent bioremediation of mining operations, offers benefits to African countries with minerals.

Environmental biotechnology manages micro-organisms that provide economic benefit to human for instance removing contaminants from water, wastewater, sludge and sediments as well as sensing pathogens in the environment or humans which in return provides protection to the public from dangerous exposure to pathogens.

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Box 5: Bangladesh is using bacteria to treat contaminated groundwater

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Naturally occurring contamination of Bangladesh's groundwater is causing what some have called the largest mass poisoning of a population in history. At least 100,000 people have already been affected, and another 50 million people are at risk. A bacterium called NT-26, recently discovered in a gold mine in Australia, may be able to help. NT-26 has the natural ability to transform arsenite, a soluble form of arsenic, into the much less toxic arsenate. The Australian Research Council is supporting research to investigate the potential of NT-26 to reduce the toxicity of arsenic dissolved in water. Knowledge of the genomic sequence of NT-26 could enhance bioremediation tools. Genome Canada plans to sequence the genomes of two arsenic-metabolizing bacteria, including NT-26.[59]

There are two biotechnological processes used for mining and metals recovery, viz. the use of micro-organisms for bioleaching, and minerals bio-oxidation. These processes are employed world-wide to extract base and precious metals using bacteria. Bioleaching at copper recovery operations, for instance, holds out many advantages over the use of conventional roasters and pressure autoclaves. This is environmentally sound as no noxious gases or toxic effluents are produced while high levels of metal recovery are achieved. The oil industry can benefit from microbial enhanced oil recovery and bioremediation of oil spills (box 6). In India, The Energy and Resources Institute (TERI) has developed a microbial (anaerobic bacterial) consortium, which enhances petroleum oil recovery by 21% under simulated conditions. In many cases, financial investments in such applications are not high. Exploiting or tapping these advances requires critical scientific and technological capacities.

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Box 6: In-situ bioremediation of crude oil spills and sludge contaminated sites

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The Gulf War highlighted the problem of crude oil spill that led to environmental degradation. In response, the Indian government started the bioremediation of crude oil spill sites by using microbes. After six years of active research, scientists at TERI developed a bacterial consortium by assembling fine bacterial species that could degrade crude oil and oily sludge. This consortium was multiplied in a bioreactor and immobilized in a carrier material. The carrier-based, *Oilzapper*, was used for bioremediation of oily sludge and oil spill sites. The *Oilzapper* has been used to treat over 8000 million tons of crude oil/oily sludge.[60]

Biotechnological tools can be harnessed in Africa for increased agricultural productivity and food security, value-added forestry-related economic sectors, health-care research and *services, industrial manufacturing and management, and processes that minimize environmental risks. Biotechnology presents Africa with enormous opportunities and all applications of biotechnology should be adopted that are appropriate to address Africa's needs and economic opportunities. African policymakers must consider how biotechnology policies can supplement and strengthen existing economic, industrial, health care, and environmental policies.*

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Technological convergence with other sectors

New technology, especially biotechnology, green chemistry and nanotechnology will drive greater eco-efficiency, resource productivity and a paradigm shift across the economy. Interfacing biotechnology with other emerging disciplines is creating a new industrial sector: nanotechnology and bioelectronics. Likewise, advances in information and communications technologies are affecting the way biosciences are conducted. These technologies are making it relatively easy to harness and apply science in such fields as genomics and proteomics. They are having enormous impact on the development of new drugs, vaccines, diagnostics and other products like contraceptives. These advances hold promise of meeting health priorities of African countries. The convergence of these technologies will make significant impact on industrial competitiveness.

Computational chemistry and genomics, bioinformatics and structural biology will continue to make contribution in speeding up the process of analysing genomes to identify candidate drugs and vaccines. This will, as a result, reduce the time needed to discover, and increase the number of, potential candidate genes of interest. Nanotechnology will make great impact on drug discovery and production. It will influence the design and nature of biosensors, biochips, drug delivery system, bioelectronics and biomaterials.[61] There are currently about 60 drugs and drug delivery systems from nanotechnology-based medical devices under test. The technology will make contributions in cellular imaging for detection of early indicators of infection or disease.

ICT has created new perspectives on the link between different industrial, agricultural, and service elements. These technologies challenge us to find new ways in which human efforts can enhance institutional life and sustain technological learning in developing economies so that gains in one area could be translated and multiplied into others. Progress in computing is providing the foundation for innovation in industries as far a field as wireless communications and genomics. This "ripple effect" will continue to expand with the exponential growth of processing power, storage capacity, and networking bandwidth.

Bioinformatics is the use of computer hardware and software to store, retrieve, and analyze large quantities of biological data. High-throughput technologies (DNA sequencers, DNA and RNA micro arrays, combinatorial chemistry, two-dimensional gel electrophoresis, and mass spectrometry) have resulted in an explosion in the volume of biological data available. Bioinformatics organizes this sea of data into meaningful databases and conducts sophisticated computer analyses (data mining) to generate answers to research questions. Bioinformatics applies computer algorithms to transform large-scale biological data sets into useful information. For example, an algorithm could be applied to quickly identify potential drug targets in pathogen genomes. Without bioinformatics, this task would be extremely laborious and prone to error, and it would take scientists years to realize the potential of genomic sequencing. Many bioinformatics algorithms are available free over the Internet, along with basic tutorials. Many can be found on the Web sites of public bioinformatics databases (see box 7). Their accessibility to scientists helps promote R&D. To help meet the worldwide demand for skilled bioinformaticians, a consortium of six universities is offering a free accredited Web-based course in bioinformatics.

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Box 7: Researchers can access free biological databases over the Internet

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Several biological databases have been established as public resources available to all over the Internet. GenBank is a massive online database of all publicly available gene sequencing. The database, which is maintained by the National Center for Biotechnology Information of the U.S. National Institutes of Health, can be accessed free of charge over the Internet. GenBank exchanges data daily with the DNA Data Bank of Japan and the European Molecular Biology Laboratory. SWISS-PROT is a protein sequence database developed by the Swiss Institute of Bioinformatics and the European Bioinformatics Institute. The Molecular Modeling Database, maintained by the National Center for Biotechnology Information, contains three-dimensional biomolecular structures, including information on biological function and the evolutionary history of large molecules.

Combinatorial methods are easily automated techniques for making many different kinds of chemical compounds. The resulting collection of compounds, known as a library, is biologically screened to select the compounds with the most therapeutic promise. First developed in the early 1980s, combinatorial chemistry has become a mainstay of drug discovery and development in industrial countries. In many cases, it has replaced the much more costly and time-consuming one-compound-at-a-time method. Combinatorial chemistry has a bearing on the health-related problems of Africa, particularly combating HIV/AIDS, malaria, and other diseases. Some pathogens, such as those that cause malaria and tuberculosis, are acquiring resistance to the only treatments available. Combinatorial chemistry could provide new or more effective medications for these diseases. It may also help industries in developing countries become competitive and economically viable in the global market. The increase in efficiency also potentially decreases costs, wastes less material, and creates fewer by-products, all of which help protect the environment. Two features make combinatorial chemistry exceptionally efficient for drug discovery and development. First, robots could do most of the preparation and screening of compounds. Second, many unique compounds can be produced from fewer experiments.

Nanotechnology is the study, design, creation, synthesis, manipulation, and application of functional materials, devices, and systems through control of matter at the atomic and molecular levels and the exploitation of novel phenomena and properties of matter at that scale.[62] At this scale, quantum effects influence matter. Matter at the nano-scale can be more chemically reactive relative to other matter; sometimes materials that are inert at the macro-scale become reactive at the nano-level. Quantum effects at the nano-level can also affect the strength and the optical, electrical, and magnetic properties of materials.

The use of nanotechnology applications for water treatment and remediation; energy storage, production, and conversion; disease diagnosis and screening; drug delivery systems; health monitoring; air pollution and remediation; food processing and storage; vector and pest detection and control; and agricultural productivity enhancement hold promise for developing countries. The convergence of nanotechnology with other emerging technologies, such as biotechnology, genomics and information technology, will significantly shift technological frontiers. Nanotechnology can contribute new tools with which to address sustainable development problems, and it can strengthen the technologies already available and make them more efficient. It will coexist with rather than replace established technologies. Advances in

nanotechnology currently target the interests of industrial countries, like applications for cosmetics, sports apparel, and various digital gadgets. Significant nanotechnology activity is already occurring in developing countries (table 4). The aim should be to encourage public discourse and consider potential benefits for the developing world.
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Table 4: Research and development on nanotechnology in selected developing countries
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Nanotechnology status	Countries	Nanotechnology activity	Example
Frontrunner	China, India, Republic of Korea	National government-funded nanotechnology program. Nanotechnology - related patents. Commercial products on the market or in development.	*China* National Center for Nanoscience and Nanotechnology. Clinical trials of nanotechnology bone scaffold. *India* Nanomaterials Science and Technology Initiative. Commercialization of nanoparticle drug delivery. *Republic of Korea* Nanotechnology Development Program. World's first carbon nanotube field emission display.
Middle ground	Brazil, Chile, the Philippines, South Africa, Thailand	Development of national government-funding nanotechnology program. Some government support (research grants). Limited industry involvement. Numerous research institutions.	*Brazil* Institute of Nanoscience, Federal University of Minas Gerais *Chile* Nanotechnology Group, Pontificia Universidad Católica de Chile *Philippines* University of the Philippines/Intel Technology Philippines optoelectronics project *Thailand* Center of Nanoscience and Nanotechnology, Mahidol University *South Africa* South African Nanotechnology Initiative
Up and comer	Argentina, Mexico	Organized government funding not yet established. Industry not yet involved. Research groups funded through various science, technology, and innovation institutions.	*Argentina* Nanoscience research group, Centro Atómico Bariloche and Instituto Balseiro. *Mexico* Department of Advanced Materials, Instituto Potosino de Investigación Científica y Tecnológica.

Biopharming, the production of pharmacological products in genetically engineered plants or animals is a field which is influencing the production and storage of vaccines and drugs. The technology offers cost advantages, in some cases leading to 90% cost-savings on conventional methods of drug production. The biopharmaceutical industry is projected to grow to about $20 billion by 2010.[63]

Biotechnology is one of several domains of science and technology that are important for economic development. The benefits both current and potential are enormous. Failure to capitalise on biotechnology will have negative consequences for Africa's development. Nations around the world are harnessing biotechnology to address needs and find economic opportunities in areas such as agriculture, environment and industry.

Advances in the life sciences are taking place in conjunction with other technologies. Therefore, those countries that develop capacity in another technological field (i.e. ICTs) are better suited to take advantages of biotechnology. Countries must seek to develop capacities in all platform technologies whose combined impact will have profound implications for long-term economic transformation. Biotechnology has wider implications for the economic system as a whole. Therefore, policies that seek to advance biotechnology cannot be separate from overall technology and economic policies; (2) Resistance to technology (in another field) has led to negative economic impacts, and similarly resistance to biotechnology will lead to the same consequences. Countries must seek to integrate biotechnology policies into overall national development policy frameworks while reducing resistance to its adoption, diffusion, and integration within economically-important sectors.

Chapter 3: Reviewing the Status of Biotechnology in Africa

Research on modern biotechnology is currently underway in African institutions. About 13 public institutions have stably transformed 21 crops, where the genes incorporated include those that confer insect, fungal, viral and bacterial resistance, protein quality improvements, herbicide tolerance, and salt and drought resistance.[64] The primary source of GM crops still remains the private sector where multinationals have made significant investments in the GM technology which is supported by a well managed regulatory process. However, Africa's low investments in biotechnology development challenge the ability of national, regional, and continental biotech initiatives to reap the potential economic, environmental, and social benefits offered by this technological tool.

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Agricultural Biotechnology

Agricultural biotechnology is arriving in Africa, where its application to indigenous crops could reap benefits. In South Africa, for example, about 20-30 percent of yellow maize and 80 percent of cotton are genetically modified varieties.[65] Estimates for the 2003/2004 production season showed that about 27 percent of total yellow maize area (for animal feed) is under GM varieties, GM white maize (for human consumption) is planted on less than 8 percent of the total white maize area.[66] Further calculations show that GM white and yellow maize occupied only about 6 and 8 percent, respectively, of the total maize area in South Africa, by 2004. The early success with GM cotton in the South Africa has not been sustained; there has been drastic declines in crop area after the introduction of the *Bt* Cotton. For instance, there was a decline of more than 50% in cotton area from about 99,000 hectares in 1998/1999 season to 51,000 hectares in 1999/2000. The 2002/2003 harvest was estimated to be around 31,000 hectares and a mere 21,200 hectares estimated for 2004/2005).[67]

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Box 8: Micropropagation in developing countries: some examples

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In China's Shandong Province, a micropropagation project that created and distributed virus-free sweet potatoes led to an increase in yields of up to 30 per cent. By 1998, productivity increases were valued at US$145 million annually, raising the agricultural income of the province's seven million sweet potato growers by three to four per cent in one season. Government subsidies helped to encourage adoption of the technology and keep the cost of the planting material low. In Kenya, the commercial micropropagation of disease-free bananas is currently being carried out. The initiative has been shown to offer significantly higher financial returns than traditional growing practices. In Vietnam, introducing improved, high-yielding potato cultivars able to resist the late-blight disease has seen yields double, from 10 to 20 tonnes per hectare. The farmers are themselves multiplying their plantlets through micropropagation, making the seed more affordable.[68]

Kenya has been engaging with non-transgenic biotechnologies, such as bio-fertilisers and tissue culture for several decades.[69] Tissue culture continues to be an important technology in Kenya in the horticulture sector particularly in citrus and pyrethrum. More recently there has been immense focus on tissue culture in bananas.[70] The first modern biotechnology to be developed in Kenya was a genetically modified (GM), virus- and weevil-resistant sweet potato. This project began in 1991 and was a public-private partnership (PPP) between the Unites States Agency for International Development (USAID), the Kenyan Agricultural Research Institute

(KARI) and the Monsanto Company, with the International Service for the Acquisition and Application of Agricultural Biotechnology (ISAAA) joining in 1999.

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Table 5: Current agricultural modern biotechnology projects in Kenya

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Product	Year of approval(s)[71]	Partners
Recombinant livestock vaccines (for diseases such as Rinderpest and Capri pox)	1995 (ad-hoc[72])	KARI, Pirbright (UK), University of California, Davis
Virus-resistant sweet potato	1998	KARI, Monsanto, USAID, ISAAA, ARC-VOPI, Danforth Centre (USA)
Insect-resistant (*Bt*) maize	2001 leaves 2003 seeds	KARI, CIMMYT, Syngenta Foundation, Rockefeller Foundation
Insect-resistant (*Bt*) cotton	2003	KARI, Monsanto
Virus-resistant Cassava	2003	KARI, Danforth Centre (USA) USAID (ABSP II)[73]

Box 9: New Rice for Africa: a tale of two techniques

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Both embryo rescue and anther culture have recently been used extensively in the successful development of the so-called New Rice for Africa (NERICA). Breeders at the Africa Rice Center (WARDA) in Benin, for example, have used both techniques to cross *Oryza sativa* (Asian rice) with *Oryza glaberrina* (African cultivated rice). Farmers have selected new rice varieties from the resulting germplasm, with qualities such as higher yields, shorter growing seasons, resistance to local stresses, and higher protein content than traditional African varieties. The new varieties have been released in Cote d'Ivoire, Nigeria and Uganda, and are being evaluated in Benin, Burkina Faso, Ethiopia, The Gambia, Malawi, Mali, Mozambique, Sierra Leone, Tanzania and Togo. WARDA researchers suggest that some 200,000 hectares will soon be under NERICA cultivation, producing about 750,000 tonnes of rice per year, and leading to an annual saving on rice imports of nearly US$90 million.[74]

The Genetic Engineering Services Unit (GESU) of the Agricultural Genetic Engineering Research Institute (AGERI) in Egypt has been actively involved in micropropagation of *Satavia rebaudiana* and mulberry, production of diagnostic ELISA kits for detecting major viruses of banana, potato, tomato and beans. Molecular markers are used for characterization of germplasm and registration of elite lines.[75] Plant genetic engineering research at AGERI has been transferring genes that confer virus resistance, bacterial resistance insect resistance, stress tolerance and fungal resistance on such crops as potato, cotton, maize, faba beans, cucurbits, wheat, banana and date palm.[76] Studies have shown that Egypt has worked on more varieties of crops than any other country in Africa but less transformation events than South Africa.[77]

Insect resistant *Bt* potato is one of the major crops that have been worked on in Egypt by AGERI in partnership with Michigan State University. Several varieties of potato were transformed for potato tuber moth resistance including a widely grown Dutch variety in Egypt, *Spunta*. *Spunta* performed well in controlling potato tuber moth but after eight years of research on the potato (1993-2001), the *Bt* potato has not been commercialised because of trade concerns with the EU. The *Bt* potato project was later in 2001 introduced in South Africa with the goal to commercialize the variety for resource-poor farmers. Just like in Egypt the *Bt* potatoes performed well in field trials but commercialisation has been delayed by the requirement of Sygenta, as owners of the *Bt* gene, to obtain full regulatory approval of the South African government before granting a commercial license. In addition, Sygenta is cautious of liability and stewardship issues when the *Bt* potatoes germplasm is transferred to neighbouring countries that do not have biosafety regulatory policies and regimes in place. The company is preparing a regulatory approval application for filing with the South African government and collecting additional safety and socio-economic field data.[78]

Drought tolerance, nitrogen use efficiency, striga resistance, stem borer and post harvest pest resistance, resistance to stem and grain diseases and grain quality are among several traits that maize improvement programmes are grappling with using transgenic and non-transgenic approaches. Several maize transgenic research programmes are underway including; the Universities of Cape Town and KwaZulu Natal in South Africa are using a gene from resurrection plant, *Xerophyta viscose*, to confer drought tolerance, and the University of Cape Town is also developing a transgenic maize streak virus resistant line. CIMMYT and KARI have been developing insect resistant transgenic maize alongside a non-transgenic effort for the same trait. The transgenic maize programme was advanced into field trial in May, 2005. Kenyatta University in Kenya has established a facility for plant transformation with maize being one of the candidate crops especially for resistance to striga and tolerance to drought.[79]

Field trials on *Bt* cotton have been carried out in several countries including Kenya, Zambia, and Zimbabwe, the crop has been commercialized in South Africa. Tanzania and Burkina Faso have recently started field trials, while Mali was slated to start field trials on the crop in 2005 (Eicher et al, 2005). The National Agricultural Research Organisation (NARO) of Uganda opened a new research laboratory in 2003 for carrying out work on genetic modification of banana with the goal to insert genes into banana that will confer resistance to Black Sigatoka and banana weevils. Several African and international institutions are involved in this partnership including KUL, CIRAD, IITA, University of Pretoria and Leeds University.[80]

Cassava has been successfully transformed for resistance to Cassava Mosaic Disease (CMD) by the Donald Danforth Plant Science Centre (USA) and materials are ready for field trials after promising green house trials carried out in the USA. The Danforth Centre and KARI in Kenya have engaged into a joint effort to obtain regulatory approval for conducting field trials in Kenya. In Nigeria, the Danforth Centre in collaboration with IITA, the National Biotechnology Development Agency (NABDA) and National Root Crops Research Institute (NRCI) have completed a biosafety application required by the government in order for consortium to carry out field trials. Discussions are underway with the government of Malawi for Danforth to collaborate with researchers at the Ministry of Agriculture and University of Malawi on a field trial.[81] It is instructive, however, that the bulk of the cassava R&D was undertaken outside Africa, which means that the benefits of technological learning for Africa are low.

Cereals as major staples of African diets have low content of vitamins, essential amino acids, iron and zinc. Large proportion of the populations in developing countries suffers from an insidious form of hunger called micronutrient malnutrition. Vitamin A deficiency is the leading contributor to child mortality in developing countries. This key nutrient is crucial for effective functioning of the immune system. Although declining, as a result of supplements, vitamin A deficiency still affects the ability of 250 million children to fight off deadly diseases like HIV/AIDS, malaria and diarrhoea. It is also the single most important cause of blindness among children.[82] Iron, zinc and amino acid deficiencies impair immunity, making humans susceptible to infections and risks of complications during childbirth and pregnancy. Also, these deficiencies profoundly impair child development.

The technology to enhance nutritive value of grains and fruits is developing rapidly and its deployment in tropical crops will yield health and economic benefits. Biotechnology is used to provide delivery systems for fighting against nutrient deficiencies in the staples. For instance, rice has been identified as an ideal food to be engineered to contain vitamin A. Golden rice, a vitamin A-rich variety, has been produced to address the serious problem caused by Vitamin A deficiency in the developing countries. However, large scale adoption and benefit of this rice in the developing world is yet to be realised. The variety is being adapted by the International Rice Research Institute (IRRI) for Philippines and other developing countries. For Bangladesh, locally developed rice varieties have been genetically engineered to produce beta-carotene. A genetically modified potato with an increased protein content of 2.5% has been developed in India.

A combination of transgenic and non-transgenic biotechnologies to enhance the nutritional content of sorghum is currently being applied by a consortium of African, American and Japanese institutions. The Council for Scientific and Industrial Research (CSIR) of South Africa, AATF, A-Harvest, FARA, the Agricultural Research Council (ARC) of South Africa are participating in a sorghum nutritional enhancement project to produce a new generation of sorghum with improved essential amino acid composition, protein and starch digestibility, iron and zinc availability and elevated levels of selected vitamins, including vitamin E. This African Biofortified Sorghum project is supported by the Grand Challenges in Global Health initiative funded largely by the Bill & Melinda Gates Foundation.

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Box 10: Bio-fertilizer production in Nigeria

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Scientists at the Obafemi Awolowo University, Ile-Ife, Nigeria have screened and selected elite strains of Bradyrhizobium (nitrogen fixing and protein forming bacteria in legume plants) which are infective, promiscuous and symbiotically effective and therefore ideal for use as legume inoculants. They also successfully identified suitable organic materials, namely: cow dung, lignite, sub-bituminous coal, and peat, which can be employed as base carriers for the Rhizobia inoculants. Thus, Nigeria has the raw materials and local technology for establishing a Bradyrhizobium inoculants industry that can provide dramatic improvement in yields of legumes such as cowpea, soybean and groundnut. Field test of the bio-fertilizer showed that it can improve yield by 50-100%. The Food and Agricultural Organization of the United Nations (Abuja Office) now use the bio-fertilizer for prosecuting the National Special Programme for Food Security of the Federal Government of Nigeria and has recorded yield improvement of 50%.

Nitrogen is a key limiting nutrient in the soils for crop production, but the price of nitrogen fertilizer has been increasing over the years to the effect that it has become unaffordable to most of small scale farmers in the rural areas. Biological nitrogen fixation (BNF) is a technology that has been adopted by many countries in Africa to circumvent this problem. It induces the multiplication of microbes in plant roots, known as biofertilizers, which then help the plant fix nitrogen from the atmosphere. Use of biofertilizers has been reported in many countries for instance Kenya, the United Republic of Tanzania, Zambia, Zimbabwe, Tunisia and Senegal.[83] For over a decade, several brands of a BNF product developed at the University of Nairobi, Kenya, have been released for commercial use, mainly for the production of leguminous crops.

Agricultural biotechnology holds promise for food security, nutrient-enhanced food commodities, and diagnostic kit development for virus detection. African countries and regions must invest in agricultural biotechnology projects and capacity-building to address long-term issues of hunger, nutrient deficiency, and threats to overall agricultural productivity caused by unfavourable climate, diseases, and soil infertility.

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Animal Health Biotechnology

In the area of animal health, biotechnology has been applied in the development of a molecular diagnostic test kit for tick-borne diseases in South Africa. The project has employed innovative solutions to diagnose and manage the increasing prevalence and negative impacts of tick-borne infections in livestock. A diagnostic kit for detecting the disease-causing pathogens in animals was launched in March 2005 through collaborative work carried out by a consortium of institutions comprising the University of Pretoria, Ultrecht University, Isogen Life Science and the ARC-Onderstepoort Veterinary Institute. Work is currently underway to transfer superior indigenous cattle genetic material of the Bosmara cattle to stocks of developing farmers using the embryo transfer technology.[84] Several live recombinant vaccines have been developed for use in primates and livestock. For instance, the recombinant *vaccinia* virus (rVV) developed for Rinderpest provides sterilizing immunity to cattle.[85] The International Livestock Research Institute is currently exploiting host immunity and parasite genomics to develop a vaccine against *Theileria parva* in cattle and preliminary trials with five candidate vaccines are currently underway.[86]

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Box 11: The European Commission promotes collaborative animal health research

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Since 1996, ICTTD (Integrated Consortium on Ticks and Tick-borne Diseases) projects have facilitated the creation of scientific networks between many institutions involved in tick-borne disease research in Europe, Africa, Latin America and China. ICTTD-3 (2004-2008) is a CA with the aim to support a research programme on tick-borne diseases, jointly executed by a consortium of 44 institutions in 28 different countries. It is a continuation of ICTTD-1 (1996-2000) and ICTTD-2 (2000-2004). The objectives of this CA are to contribute to a better understanding of tick-host-pathogen interactions and to identify means of improved control of ticks and tick-borne diseases of livestock in (sub)tropical countries.

Other tick-borne related projects: TRYPADVAC-2 (the Development of an "anti-disease" vaccine and diagnostic tests for African trypanosomiasis, 2005-2008), a follow up of TRYPADVAC (2000-2004). The main objectives of this STREP are: improve livestock productivity in trypanosomiasis-affected areas; develop and validate antibody and antigen detection tests.

RP/PPR MARKVAC (Development of marker vaccines, companion diagnostic tests and improvement of epidemiological knowledge to facilitate control of Rinderpest and peste des petits ruminants viruses, 2005-2009). The main objectives of this STREP are: define, contain and eliminate the last foci of rinderpest and to improve PPR control; allow differentiation between vaccinated/infected animals; strengthen rinderpest and PPR surveillance and emergency preparedness.

The National Veterinary Institute of Ethiopia has the capability to study and screen micro-organisms for biological compounds suitable for vaccines and therapeutic purposes. It produces viral vaccines against rinderpest, Sheep-pox, Newcastle, African horse sickness, foot and mouth disease and bacterial vaccines against contagious *Bovine pleuropneumonia*, anthrax, and blackleg, among others. It has developed a recombinant DNA-based vaccine against Rinderpest in collaboration with University of Davis, California. The Institute is also a regional office for quality control of livestock vaccines for FAO.[87]

The University of Ibadan, Nigeria, has a collaborative research project on DNA sequencing of vaccines for the prevention of the infectious *bursa* disease (a.k.a. Gumboro disease) in poultry. Gumboro disease presently has no curative drug; it is a mass killer of fowls; and occurs worldwide with differentiated strains of the causative virus. The research project attempts to develop new vaccines that are consistently effective for the prevention of the disease.

It involves DNA sequencing of the Nigerian strain of the Gumboro virus and the new vaccines that may prevent it. Samples of the virus taken from farms in three Southwest states of Nigeria are currently being investigated. Results from DNA sequencing of existing vaccines in Nigeria showed that they are largely inappropriate for the strain of the virus found in Nigeria. There are currently more than fourteen vaccines in Nigeria, but only one of them is manufactured domestically at the Veterinary Research Institute, Vom. The DNA sequencing of the Vom vaccine is also undertaken to determine means of making it more effective.[88]

Animal biotechnology can help develop vaccines for livestock diseases and infections that threaten food security. African political, research, and higher education institutions must invest in animal biotechnology R&D to stem the increasing prevalence of livestock diseases and infection.

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Forestry biotechnology

Most forestry biotechnology is still at laboratory level; Africa is likely to benefit from biotech in areas like characterization of genetic diversity of indigenous tree species, micropropagation for reforestation programmes, technology that is likely to dominate worldwide for many years to come. Africa contributes less than 4% to world activity in this area (table 6), despite the continent holding about 16% of world's forest cover.[89]

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Table 6: Africa's involvement in forestry biotechnology as percentage of global activity[90]

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Biotechnology activity	Percent for Africa
Distribution of forest biotechnology activities excluding genetic modification	3
Forest genetic diversity characterization	3
Forest genetic diversity characterization by the region of the origin of the species studied	4
Distribution of research related to mapping, marker-assisted selection and genomics in forestry species by region	2
Distribution of research related to mapping, marker-assisted selection and genomics in forestry species by region of origin of the species studied	<1
Distribution of micropropagation activities by region	3
Distribution of micropropagation activities by region of the origin of species studied	2
Distribution of data set entries on genetic modification by region of the world	<1

Forestry biotechnology can help Africa benefit in areas of tree species biodiversity and reforestation. Africa must upgrade and expand its limited forestry biotechnology programs for economic benefits to be reaped in the world economy.

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Health and Medical Biotechnology

Medicine and health care are set to benefit enormously from modern biotechnology. Biotechnology applications can be linked directly to addressing the Millennium Development Goals, especially the health related ones.[91] The benefits, in fact, appear likely to extend beyond immediate applications to health care to energizing innovation in various related industries, and in the long run, to improving national and regional economies. Some of these issues have been discussed in the report of the UN Millennium Project Task Force on Science, Technology and Innovation.[92]

There are also benefits to be derived from the convergence, on the one hand, between different technologies such as biotechnology and nanotechnology; and on the other between different areas of application such as between health and agriculture.

When discussing how biotechnologies might help improve the health of people in Africa it is important to be as specific as possible in terms of actual applications and to project a few years ahead in a realistic way through a foresight exercise. A recent study of this nature has identified the following applications of modern biotechnology that are likely to improve the health of people in developing countries:

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Table 7: Top Ten Biotechnologies for Improving Health in Developing Countries[93]

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Rank	Biotechnological area or application	Score
1	Modified molecular diagnostic techniques for infectious diseases	288
2	Technologies for recombinant vaccine development for infectious diseases	262
3	Technologies for drug and vaccine delivery	245
4	Bioremediation to improve environmental quality	193
5	Sequencing pathogen genomes to improve diagnosis/vaccine/drug development	180
6	Women controlled systems against sexually transmitted diseases	171
7	Bioinformatics for drug target identification	168
8	Nutrient enriched transgenic plants to counter deficiencies	159
9	Recombinant technology for therapeutic product development	155
10	Combinatory chemistry for drug discovery	129

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Table 8: Lessons learned from selected case studies

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Brazil

- Focus on developing a strong science capacity
- Promote linkages and exploit existing strengths in disparate fields
- Exploit local biodiversity for health
- Gain access to key actors

China

- Provide long-term government support
- Attract expatriate professionals
- Ensure that biotechnology development goes hand-in-hand with regulation
- Leverage large population base

Cuba

- Ensure long-term governmental vision and policy coherence
- Promote domestic integration to spur innovation
- Capitalize on international linkages
- Tap into national pride

Egypt

- Focus on health needs
- Gain access to key actors
- Take advantage of international linkages

India

- Leverage strengths when cultivating linkages
- Meet international standards
- Use competitive advantage
- Pay attention to the regulatory environment

South Africa

- Focus government policy on public health needs
- Exploit both indigenous knowledge and science-based innovations
- Develop local R&D infrastructure for self-reliance

South Korea

- Create a mix of small and large firms
- Exploit existing competitive advantages
- Go global

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Box 12: Grand Challenges in Global Health[94]
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The 14 Grand Challenges in Global Health serve seven long-term goals to improve health in the developing world

1. Improve Childhood Vaccines

Grand Challenge #1: Create Effective Single-Dose Vaccines
Grand Challenge #2: Prepare Vaccines that Do Not Require Refrigeration
Grand Challenge #3: Develop Needle-Free Vaccine Delivery Systems

2. Create New Vaccines

Grand Challenge #4: Devise Testing Systems for New Vaccines
Grand Challenge #5: Design Antigens for Protective Immunity
Grand Challenge #6: Learn About Immunological Responses

3. Control Insects that Transmit Agents of Disease

Grand Challenge #7: Develop Genetic Strategy to Control Insects
Grand Challenge #8: Develop Chemical Strategy to Control Insects

4. Improve Nutrition to Promote Health

Grand Challenge #9: Create a Nutrient-Rich Staple Plant Species

5. Improve Drug Treatment of Infectious Diseases

Grand Challenge #10: Find Drugs and Delivery Systems to Limit Drug Resistance

6. Cure Latent and Chronic Infection

Grand Challenge #11: Create Therapies that Can Cure Latent Infection
Grand Challenge #12: Create Immunological Methods to Cure Latent Infection

7. Measure Health Status Accurately and Economically in Developing Countries

Grand Challenge #13: Develop Technologies to Assess Population Health
Grand Challenge #14: Develop Versatile Diagnostic Tools

There are already good examples of developing countries, including in Africa, harnessing modern biotechnology in addressing local health problems. A recent study of the national health biotechnology innovation systems of Cuba, Brazil, South Africa, Egypt, India, China and (for comparison) South Korea, highlighted the early successes of these "innovation developing countries".[95] More importantly the series of studies highlighted the lessons learnt by these countries and the good practices likely to lead to success. African countries might benefit from these lessons and good practices, summarized in table 8.

One way of projecting into the future in terms of what might be important areas of applications is to follow where investments in research are being made with a long term view to addressing major health problems. The Bill and Melinda Gates Foundation (BMGF) has recently worked to identify the Grand Challenges in Global Health (shown in box 12 below) and then, together with some other (but much smaller) funders, put in US$ 437 million into just 43 research projects to address the challenges.[96]

Human and medical biotechnology can be harnessed to address Africa's health care systems, with implications for energizing industry-related innovations and, in the long run, improved national and regional economies. African countries and regions should (1) Study the major players contributing to innovation in health biotechnology, including those in the private sector, with a particular focus on knowledge flows and value creation. (2) Identify strengths and weaknesses in efficient use of resources, e.g. ways of joint decision-making among different ministries. For example, the Ministries of (Higher) Education and of Health might be brought closer together. (3) Analyze the close linkages between macroeconomics and health. Health is an intrinsic human right as well as a central input to poverty reduction and socioeconomic development.[97]
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Industrial biotechnology

There is no tangible evidence of industrial biotechnology research in Africa. Ghana recently inaugurated a 22-member implementation committee for the development of bio- fuel in 2005. The committee was mandated to develop guidelines to facilitate and regulate regimes for the production of bio-fuel with emphasis on liquid bio-fuels such as bio-diesel and bio-alcohol as substitute for diesel and petrol. The Government has pledged to create the enabling environment in terms of favourable fiscal and regulatory regimes to ensure effective private sector participation in the development of viable substitutes to fossil fuel within the shortest time. Ghana spent 775 million dollars on oil imports in 2005, which was about 28 per cent of export earnings which has compelled the country to hasten her plans to produce bio-fuel in commercial quantities as a result of escalating world crude oil prices. It is expected that a market demand of 10.5 billion litres of bio-diesel will be created by 2010. The country has favourable climatic and soil conditions for most of the crops used in the production of bio-fuel.

The most promising areas for Africa in the area of industrial biotechnology is in development of bio-fuels, value addition to its raw materials, and conversion of waste into useful products. Industrial biotech can cut the costs of investments while improving the quality of products, provide flexible processing and manufacturing platforms that could easily be modified and adapted. Africa must (1) develop a comprehensive industrial biotechnology R&D agenda; and (2 fast track its program to create the enabling environment for effective private sector participation in the development of bio-fuels.

Environmental biotechnology

Environmental biotechnology can greatly help to stop the degradation of African environment and contribute to the reduction of use of pesticides, improvement of plant drought tolerance, nitrogen use efficiency, reforestation, and waste treatment. The International Centre for Insect Physiology and Ecology (ICIPE) in Nairobi, Kenya, has developed the capability to launch pilot-scale production of a number of environmentally friendly products, including food, fibre, cosmetics, pharmaceuticals and products for biological management of pests. ICIPE researches on insects and other arthropods that affect human lives and develops products to mitigate their effects. These products are crucial for non-chemical environmental management in the tropics. Specific classes of products already developed or at various stages of development include:

(a) Bioactive botanical products from the Neem tree for the management of pests and for the treatment of human health disorders;
(b) Environmentally friendly traps targeting harmful Arthropods such as the tsetse fly;
(c) Environmentally friendly pest management products, for example, *Bt*–based bio-pesticides;
(d) Pheromone attractants, repellents and behaviour modifiers that target locusts, mosquitoes, tsetse flies and stem borers; and,
(e) Bio-based anti-feedants aimed at insect and tick pests.[98]

The Addis Ababa University has been researching on wastewater treatment with efficient bacteria to develop and optimise process technologies for removal of biological nitrogen and organic pollutants from tannery wastewater in Ethiopia. Potential micro-organisms with high bioremediation capacity are isolated and characterized using molecular techniques. In line with the environmental protection strategy of one of the major multinational breweries in Nigeria, a professor of microbiology at the University of Ibadan was contracted to help solve the problem of waste oil in wastewater effluent. The scientist solved the problem through the application of an organic digester, which he had earlier invented. The industrial wastewater is dosed with the organic digester called '*Oso biodegrader plus*' (OBD+) at various points before the effluent reaches the lagoon. The OBD+ contains microbes that breakdown toxins and digest oil and grease (see box 13 below).

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Box 13: Discovery of '*Oso biodegrader plus*' (OBD+)

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The research started in 1985 after the discovery of an invasion of the Lagos lagoon by water hyacinth in 1984/85. The water hyacinth invasion became a national problem, and the scientist was nominated to serve on a national committee to solve the 'strange weed problem'. His research discovered the possible uses of water hyacinth. The weed is 95% water, and its fibre could be used for mat, pulp and paper, animal feed, manure, mushroom compost, and as a carrier medium for micro-organisms. In 1992, he discovered that the water hyacinth could successfully serve as a carrier medium for microbes that breakdown toxins and digest oil and grease. He further experimented and found that the resulting substance, which could be either in powder or suspension form, can be produced on a commercial scale. He termed the invention OBD+, and got it patented in Nigeria in 1997. He currently produces OBD+ in a small factory to serve his clients. Apart from its efficacy in treating oil and grease, OBD+ has also been proven to breakdown refuse into fertiliser in four to six weeks, crude oil into less objectionable substances, and industrial sewage into nutrients on which water hyacinth thrives.[99]

African countries are already harnessing environmental biotechnology to manufacture products aimed at non-chemical environmental management in the tropics as well as to develop and optimise process technologies for removal of biological nitrogen and organic pollutants from the environment. African countries and regions should more fully integrate environmental biotechnology into its environmental protection strategies and policies and launch pilot-scale production of environmentally friendly products including food, fibre, cosmetics, pharmaceutical and products for biological management of pests.

Chapter 4: Identifying Critical Capabilities

To effectively tap the economic opportunities presented by modern biotechnology and ensure that the technology and related scientific advances are appropriately governed, African countries will need to take specific actions to build their scientific and technological capacities. These capacities are defined to include the ability to identify specific opportunities and to harness human and institutional resources to apply modern biotechnology in realizing those opportunities. The capacities comprise human, financial, and infrastructural resources as well as institutions—policies, laws and organizations. Organizations include informal social agencies or arrangements. Configuring and using all these will determine scientific and technological capacity. Capacity building therefore needs to be done in a systematic and integrated manner.

There are at least four areas of capacity building that African countries need to collectively focus on. These are: (a) investing in technology-related physical infrastructure; (b) strengthening the human resource base; (c) building institutional; (d) broadening societal competence in technical matters; and (e) funding innovation initiatives.

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Physical Capabilities (Infrastructure Development)

The concepts of innovation systems and interactive relationships stress the links between firms, educational and research institutes and governments. These concepts cannot be implemented without the infrastructure that supports and facilitates the connections. Particularly in the era of globalisation and knowledge-based economies, the quality and functionality of ICT and logistical infrastructure are essential for the development of academic, research, and market institutions. For these reasons, the construction and maintenance of infrastructure represents a technological and institutional investment. Infrastructure is therefore a fundamental element of a comprehensive and effective science, technology and innovation policy.

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Table 9: Irrigation in Africa and Asia 1961/63 to 1997/99

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	Irrigated land in use (million hectares)		
	1961/1963	1979/1981	1997/1999
East Asia	40	59	70
South Asia	37	56	81
Sub-Saharan Africa	3	4	5

Poor infrastructure and inadequate infrastructure services are among the major factors that hinder efforts to develop Africa.[100] The presence of supporting infrastructure is often fundamental to uptake of effective innovation and was a major factor in Asia's successful green revolution.[101] Roads are critical to supporting input and output marketing,[102] but the expansion of irrigation probably constituted the most important element of supportive investment.[103] The advancement of information technology, and its rapid diffusion in recent years, could not have happened without basic telecommunications infrastructure.[104] Many high-tech firms, such as those in the semiconductor industry, require reliable electric power and efficient logistical networks. In the manufacturing and retail sectors, efficient transportation and logistical networks allow firms to adopt process and organisational innovations, such as the just-in-time approach to supply chain management.[105]

Infrastructure presents a particular challenge in Africa, where the levels of irrigation, for example, are much lower than in Asia (see table 8). By 2030, it is projected that about 80% of future agricultural production gains will be made from intensification (which is in part dependent on irrigation), with a much smaller proportion through land expansion.[106] Without adequate infrastructure, African countries will not be able to harness the power of science, technology and innovation to meet development objectives and be competitive in international markets.

Globalisation of trade and investment demands that countries upgrade their technological capabilities as a source of competitive advantage.[107] Infrastructure contributes to technological development in almost all sectors of the economy. It serves as the foundation of technological development; its establishment represents, in effect, technological and institutional investment. The infrastructure development process also provides an opportunity for technological learning.[108]

We define infrastructure broadly as the facilities, structures and associated equipment and services that facilitate the flows of goods and services between individuals, firms and governments.[109] Conventional infrastructure includes: public utilities, such as energy, telecommunications, water supply, sanitation and sewerage, and waste disposal; public works, such as irrigation systems, schools, housing and hospitals; transport sectors, such as roads, railways, ports, waterways and airports; and research facilities such as laboratories and related equipment. Infrastructure services include the provision, operation, and maintenance of the physical facilities of the infrastructure.

Because infrastructure services are intermediate inputs into production, their costs directly affect firms' profitability and competitiveness. Infrastructure services also affect the productivity of other production factors. Electric power allows firms to shift from manual to electrical machinery. Extensive transport networks reduce workers' commuting time. Telecommunications networks facilitate flows of information. As an "unpaid factor of production," infrastructure increases the returns to labour and other capital. The availability of infrastructure may also attract firms to certain locations, which create agglomeration economies and reduce factor and transactions costs.[110]

Infrastructure and technology development often reinforce each other. Expanded use of technology in development depends on the existence of infrastructure; just like the development of new technologies contribute to infrastructure development. Infrastructure contributes to technological development by providing opportunities for learning associated with the acquisition of technology. For example, advances in communications and data- processing technologies assisted the development of intelligent transportation systems for efficient traffic management. The use of geographic information systems and remote-sensing technologies enables engineers to identify groundwater resources in urban and rural areas. Thus, the construction and maintenance of infrastructure represents a technological and institutional investment. Because of the fundamental role of infrastructure in the economy, the learning process in infrastructure development is a crucial element of overall technological learning process. This dynamic aspect of infrastructure is often overlooked.[111]

Every stage of an infrastructure project, from planning and design through construction and operation, involves the application of a wide range of technologies and institutional and management arrangements. Because infrastructure facilities and services are complex physical, organizational, and institutional systems, deep understanding and adequate capabilities are required on the part of engineers, managers, government officials, and others involved in these projects. Infrastructure is also one of the most important factors in attracting foreign direct investment, in addition to being itself an investment target. It is one of the key factors that investors consider in determining the location, scope, and scale of their investments.

Poor infrastructure and inadequate infrastructure services are among the major factors that hinder efforts to develop Africa and harness the tools of biotechnology to aid in that development. Africa should immediately expand and create infrastructure development programs that upgrade strategically important infrastructure in order to tap into the opportunities that may arise from biotechnology. Research and development activities for the development, operation and maintenance of infrastructure should also be promoted, and linkages should be established with both domestic and overseas research networks.

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Human capabilities

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Human capabilities, defined to cover skills, experiences and entrepreneurial culture, are main determinants of economic development. Economic transformations are largely determined by investments to build and use human capabilities. Those countries that ignore the importance of building human capabilities often stay at the periphery of international economic development and trade. Universities, research institutions and private companies as well as social institutions such as women groups and families play a major role in building human capabilities. They stimulate human creativity and are important vehicles for releasing human potential into economic activity. These institutions thus need to be nurtured and strengthened so that they play their major role as sources and users of human capabilities for economic growth and sustainable development.

Countries that utilise and benefit from scientific discoveries and facilities located elsewhere have skilled researchers who maintain constant communication and work frequently in collaboration with scientists around the world. These countries have therefore invested in creating a cadre of scientists capable of peering with other scientists on specific regional and international projects.

One of the barriers to Africa's engagement with wider applications of biotechnology is the inadequate number of African scientists and technicians with skills in such specialized areas as molecular biology, biochemistry and bioinformatics. African countries have not invested adequately in the creation and/or mobilization of scientific and technical skills in the new biosciences. Most of Africa has recorded declining enrolments in science, engineering and technical courses at universities and higher education institutions. Participation of women in science and engineering is even lower. While women should play a major role in the development and application of modern biotechnology for Africa's socio-economic transformation, they constitute a relatively small number of the total population of scientists and engineers.

However, the greatest challenge for most African countries relates to first and foremost mobilizing and efficiently utilizing existing national scientific expertise. Many of the countries have not been able to devise strategies to identify and mobilize available expertise to bear on the development of specific biotechnology products and processes. Barriers to entry into modern biotechnology can be broken through learning-by-doing and efficient use of such traditional techniques as tissue culture. Moreover, such precedents as the development of diagnostic kits for tropical diseases in Africa and work on developing vaccines for diseases such as hepatitis in Asia confirm that a small group of well-trained scientists can contribute significantly to the development and safe use of biotechnology.

Addressing the challenges of mobilising the human resources needed for biotechnology development will require deliberate national and regional human resources development strategies. The development of new generations of African scientists and technicians needs to be at the core of the continent's common strategy and actions aimed at building scientific and technological capacities. This should be guided by or based on the multidisciplinary nature of modern biotechnology.

One specific action that African countries should collectively consider and take is developing a continental biotechnology curriculum that focuses on specific areas and targets that offer high economic potential for the regions and the continent. To do this Africa should draw lessons from Southeast Asia and such international programmes as those of the International Centre for Genetic Engineering and Biotechnology (ICGEB) that developed and offer regional training courses. In addition to scientific aspects, emphasis needs to be placed on creating entrepreneurial skills and culture for commercializing biotechnology.

Another action-oriented recommendation for African countries is establishing a consortium of clearly identified and designated universities that should develop and offer regional biotechnology training courses. Such a consortium could be part of the NEPAD/African Biosciences Initiative, explicitly linked to the local innovation areas so that training and research are integrated. Linking the proposed consortium to the local innovation areas would also enable the universities to access and use modern facilities.

Strategies should first and foremost focus on strengthening universities and higher education institutions to become the locus of creating and mobilizing skills in specialized biotechnology areas, including engineering. It is crucial to identify and devote some African universities for training to meet specific regional biotechnology priorities. Secondly, human resource development strategies will need to give deliberate attention to increasing women's enrolment in biosciences and engineering courses at higher education institutions. Emphasis could be put on improving and making R&D infrastructure meet the special needs of women e.g., part-time work, flexible hours, infant care support, extended maternity/child care leave, and research programmes to address issues important to women. In addition, funding schemes that provide incentives for girls to enrol in science and engineering courses need to be explored.

Continental challenges require a refocusing and balancing of educational efforts to include the focus on sciences in general and life sciences in particular. There is an urgent need to develop and expand national and regional human resources development strategies that include: (1) a continental biotechnology curriculum that focuses on specific areas and targets that offer high economic potential for the regions and the continent; (2) a consortium of clearly identified and designated universities that should develop and offer regional biotechnology training courses; (3) a focus on female recruitment in the sciences and engineering.

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Institutional capabilities

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Regional R&D capabilities

While it is prudent for Africa to emphasise international trade, doing so requires greater investment in developing capabilities to trade, including technological innovation, the development of business and human resources, and institutional strengthening. The ability of countries and firms to innovate, both in technical and managerial ways, is largely determined by strategic alliances they forge both within their industrial landscape and across sectors. Furthermore, for industrial firms to become successful in generating new innovations they often have to create partnerships with public R&D institutions. This is clearly manifest in such fields as biotechnology: relatively strong and strategic partnerships between university R&D activities and operations of companies abound.

Overall, regional integration agreements increasingly recognise and articulate the role of cooperation in fostering the application of science and technology for sustainable development. Scientific and technological development is a learning process that is largely achieved by countries through cooperative or collaborative efforts of sharing experiences, information, infrastructure and such other resources as human and financial. Today no country can secure scientific advances and technological progress without interacting with its peers and neighbours. A common feature of these agreements is their recognition of the importance of science and technology (S&T) in economic development; indeed, most of them have provisions for S&T cooperation.[112]

The integration of S&T considerations into the regional agreements is also a recognition of the smallness of individual African economies and hence their inability to marshal adequate scientific and technological resources for development. Many are poorly endowed with human, physical and financial resources necessary to develop and harness science and technology for economic change. Thus, economies of scale would dictate that such countries combine their resources for greater effectiveness. Africa, therefore, has a wide range of regional instruments—policies, programmes, protocols and treaties—that articulate the importance of S&T cooperation. The impact of bigger markets on technological innovation, and the economies of scale and the diffusion of technical skills arising from infrastructure development are some of the most important gains Africa could make from regional integration.[113]

Weak regional science and technology institutions and the failure to adjust regional organisations have, however, made it difficult to implement regional agreements.[114] Many African countries continue to work with isolated R&D systems often with limited scientific and technical expertise and financial resources. The continent, as a whole, has spread its limited resources too thinly across science and technology fields.

In many cases existing science infrastructure of the relatively well-to-do countries of the region is not accessible to others that desperately require it. Given the wide applications of biotechnology and the fact that many African countries may not individually possess the requisite scientific and technological capacities to exploit the applications, it is crucial that African countries identify specific priority areas that offer high potential for regional R&D and product development.

Most regional and sub-regional Treaties make explicit reference to the need to strengthen cooperation in various S&T fields. Article 13 of the Constitutive Act of the African Union (AU) gives authority to the Executive Committee of the AU to formulate policies that promote science and technology cooperation. Similar provisions are found in the Common Market for Eastern and Southern African (COMESA). Article 100(d) of COMESA's treaty calls on member countries to cooperate to promote "industrial research and development, the transfer, adaptation and development of technology, training, management and consultancy services through the establishment of joint industrial support institutions and other infrastructural facilities".

The Treaty also aims at promoting co-operation in the creation of an enabling environment for foreign, cross border and domestic investment including the joint promotion of research and adaptation of science and technology for development.

The Treaty establishing the Economic Commission for West African States (ECOWAS), in Article 27 (Science and Technology), requires Member States to: strengthen their national scientific and technological capabilities; ensure the proper application of science and technology to the development of agriculture, transport and communications, industry, health and hygiene, energy, education and manpower and the conservation of the environment; strengthen existing scientific research institutions; harmonize at the community level, their national policies on scientific and technological research with a view to facilitating their integration into national economic and social development plans; and co-ordinate their position on all scientific and technical questions forming the subject of international negotiation.

The ability of African countries and firms to innovate in biotechnology is largely determined by strategic alliances they forge geographically and across sectors. African countries should identify specific biotechnology priority areas that offer high potential for regional R&D and product development and integrate these priorities into African regionalization processes and policies.

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Research and development

One of the preconditions for a country's scientific and technological development is the existence of good physical infrastructure. Research laboratories with appropriate equipment are very important ingredients of technological development and thus national economic growth. Yet in many developing countries, particularly in Africa, research laboratories and related infrastructure have been ignored. Africa's economic planning and related investments do not often foster the development and maintenance of infrastructure for research.[115]

As the rest of the world has advanced technologically, Africa has fallen relatively further behind. From 1988 to 2001, the number of scientific articles published worldwide grew by 40 percent. Africa not only failed to keep pace with this growth, publication counts actually declined by 12 percent in absolute terms. In 1988, Africa accounted for 1.26% of all scientific publications; by 2001 its share was only 0.76%.[116] Of the leading 10 countries, Kenya, Nigeria, Senegal, South Africa and Zimbabwe all published fewer articles in 2001 than in 1988. Of the countries that had increases (Cameroon, Ethiopia, Ghana, Tanzania, Uganda and others), none published more than 100 articles annually at any time from 1988 to 2001. Capacity is insufficient even to stay meaningfully connected to global advances in science and technology. Opportunities to transfer and adapt knowledge – the same knowledge that is producing concrete benefits elsewhere – remain mostly unknown and vastly underexploited in Africa.[117]

The current trends and the levels of investment in biotechnology R&D activities in Africa do not match the amount of political rhetoric on the subject. In the last five years, political statements in support of biotechnology in general have been expressed by different African leaders, both at the national and continental level.[118] Yet, public investments in biotechnology R&D remain minimal. For example, it estimated that, in most African countries, government funding to general biotechnology R&D activities does not exceed US$250,000 per year.[119] Consequently, Africa's R&D activities in gene-based technologies have been curtailed.

Globally, agricultural research has experienced a dramatic decline in public-sector funding, which has now been overtaken by the private sector. Syngenta, for example, invests around £450 million ($800 million) annually in R&D, making it the largest investor in agricultural research globally.[120] Yet such research is inevitably targeted towards the major existing markets. Public support for research in Africa has been lukewarm and attempts at public-private partnerships remain inconsistent and half-hearted. In biotechnology, African governments have failed to match their rhetoric with major infusion of investment funding to scale up R&D.

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Africa's meagre R&D investments impair its capacity to stay meaningfully connected to global advances in biotechnology and its ability to transfer, adapt, and exploit life sciences knowledge for the benefit of its citizens. African leaders, at the local, national, regional, and continental levels, must significantly increase public investments in biotechnology R&D.

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Capabilities in higher education

Africa's knowledge institutions, particularly universities and research institutes, are confronted with tremendous challenges and opportunity: how to contribute to economic dynamism as investment climates improve? How to become conduits for economically valuable knowledge and skills in nascent national innovation systems? This challenge comes as many African university systems are emerging from the crises of the past two decades. As they grow stronger, they are finding the world a different place, changed by rapid global advancement of technology. These changes cannot help but affect the missions and modus operandi. In deciding how to shape themselves now, aspirations for the future may be a better guide than traditions of the past.[121]

Three trends or facts bear significantly on how African knowledge institutions may want to reposition themselves:[122]

(a) the need for strong capacity in fundamental disciplines of science, technology and engineering to connect to growing global stocks of knowledge;
(b) the need for explicit national technology-learning strategies and key partnerships to make knowledge flow to where it is needed in production; and
(c) the opportunity to take advantage of technological "latecomer" status, and apply or adapt existing technologies to the continent's most pressing problems.

Knowledge institutions, especially universities, face two additional challenges that will shape their ability to respond:

(a) exploding enrolment growth and demand for tertiary education; and
(b) limitations of public resources for investment in universities.

A key aspect of institutional building pertains to strengthening African universities and other institutions of higher education to make them the loci of creating new skills and producing scientific knowledge. This should include improving or upgrading their R&D infrastructure as well as reorienting their missions to regional and continental economic priorities. Universities and technical colleges' programmes will need to provide more space and other resources for African women scientists to participate in R&D.

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Box 14: BIO-EARN

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The mission of the BIO-EARN Programme is to build capacity in biotechnology in Ethiopia, Kenya, Tanzania and Uganda and promote appropriate research and related policies. The programme aims to use biotechnology in a sustainable manner in order to help improve livelihoods, ensure food security and safeguard the environment. Over the last five years, the programme has worked towards building capacity in order to make use of and work towards overcoming the challenges of modern biotechnology and biosafety as well as towards promoting appropriate related policies under local conditions in the region. It has been able to distinguish itself so far in combining several aspects of biotechnology development within one programme.

Twenty BIO-EARN research projects undertaken by PhD students have been running since 1999. Specific outputs include characterisation of coffee germplasm in Tanzania and Ethiopia assisting local breeding efforts and East African coffee production; characterisation and development of a robust tissue culture protocol which will assist production of disease free plantlets and improve food security in Ethiopia; identification of cynogenic glucoside molecular markers and participatory breeding systems which may facilitate cassava breeding efforts and improve food security in East Africa; cloning genes involved in oil production in sesame enabling future production of oil crops with altered oil quality, diversifying and adding value to East African agricultural production; development and optimisation of the biological treatment of selected waste water types in Ethiopia, Tanzania and Uganda improving water and environment quality in East Africa; and initial protocol developed for biomethanation of organic refuse for production of biogas and fertiliser.

The universities in Africa have a key role to play in bridging the genetic divide where they have potential to promote technological development. A strong knowledge base needs to be created and nurtured. African universities, like their developing country counterparts, need to promote networking inside and outside their institutions and both locally and internationally. The current state of the African universities needs to be addressed; one of having outdated curricula, under motivated faculty, poor management and limited research and development programmes. There is need for emergence of entrepreneurial models of academic research. This will entail the universities accepting that their responsibilities is not just teaching and carrying out research; but also to contribute directly to economic growth of the society.

The current African situation is forcing educational institutions to consider whether their missions connect with the development challenges of the continent Reinventing African educational systems with the focus on S&T is critical for the continents economic recovery. Recommendation: African universities and other institutions of higher education must: (1) create new skills; (2) produce scientific knowledge; (3) improve and upgrade R&D infrastructure; (4) reorient their missions to regional and continental economic priorities; and (5) provide more space and other resources for African women scientists to participate in R&D.

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Commercialization capabilities

It is clear that most of Africa's productive sectors are in stagnation. Agricultural and manufacturing sectors continue to perform poorly despite policy reforms targeted at improving efficiency. More than twenty-three sub-Saharan Africa countries are experiencing food emergencies because their agricultural sectors are performing poorly, largely because of low technological base and weak poorly developed markets.[123] Other factors include poor physical infrastructure, which impedes the effective distribution and marketing, degraded soil fertility, uncertain land tenure, inadequate access to credit, limited irrigation possibilities, including competition for scarce water resources, and the threat of climate change. These are compounded by the unfolding devastation caused by HIV/AIDS on adult populations.

Industrial manufacturing remains a core component of long-term enterprise learning. Historically, industry has been a critical source and diffuser of technological progress and associated skills. Manufacturing is a driver of innovation because it affords opportunity for experimentation in engineering, production, quality and the management of organisations. Enterprises with manufacturing capability diffuse new processes, organisational practices and learning opportunities for the labour force.[124] The existing constraints on private-sector investment in Africa affect the manufacturing sector particularly harshly. For example, opaque tax and regulatory regimes undermine investor confidence. Manufacturing, production and distribution processes attract a high degree of state attention and bureaucracy, with the concomitant possibility of corruption depressing efficiency at all levels.[125]

Much of the discussion of business development in Africa continues to focus on the role of multinational corporations, with only limited policy interest in the importance of domestic businesses as sources of economic dynamism.[126] However, small and medium-sized enterprises account for over 90 percent of the private sector worldwide.[127] The critical nature of technological progress offers a significant role for small-scale technology entrepreneurship in employment generation, facilitating structural change and stimulating growth.

Small and medium size enterprises have an essential role to play, but investments and incentives to build them have been generally lacking in Africa, with public and foreign investments still focused on large infrastructure and industrial projects.[128] Consequently, the barriers to the development of this sector in Africa are numerous:

(a) limited local demand, with limited market development;
(b) financial constraints due to low income and savings, and inadequate long-term credit;
(c) lack of support, knowledge and experience in business and management;
(d) shortage of skilled and experienced manpower;
(e) lack of business and market information;
(f) insufficient intellectual property rights protection; and
(g) regulatory barriers and inconsistent government policies.

Private-public sector cooperation or partnerships in R&D has over the past two decades become a prominent form of organising and managing technological innovation mainly in developed countries. The pressure of international competition, increased diffusion of information and communication technologies, declining public financing of R&D and the opening up of national economies, including liberal foreign direct investment and trade regimes, as well as strengthened IPR, have facilitated increased private industry engagement in R&D.

In the area of biotechnology, the private sector is perhaps the largest holder of technological information and knowledge. A large and growing portion of the scientific information and investments in genetic engineering are held by private sector mainly in the industrialized world. African countries are yet to tap into this pool to build their technological competence in biotechnology. Public research institutions in Africa have not developed the strategic linkages to access this information. An attempt to improve Africa's access to global technology has been initiated through the African Agricultural Technology Foundation (AATF). The AATF helps farmers – and African researchers – to access productivity-enhancing technologies held by the private sector that would otherwise not be available, owing to intellectual property rights (see box 15 below).

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Box 15: Facilitating the transfer of agricultural technology
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The African Agricultural Technology Foundation is a not-for-profit foundation that facilitates public-private partnerships for the transfer of technologies to smallholder farmers in sub-Saharan Africa. The technologies are aimed at improving food security and reducing poverty. The foundation will with time reduce transaction costs to both the providers of technologies and recipients. AAT is also involved in catalysing reforms and creation of agricultural markets, a role where the Foundation assists relevant institutions to self-organise so that they can efficiently and effectively absorb new technology concepts and adopt them for productive use.

The commercialization of biotechnology is effectively achieved with the participation of the private sector. The economic history of public R&D in many parts of the world demonstrates that public agencies have limited capacity to engage in the commercialization of new technological innovations.
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Box 16: The Case of South Africa's BioPAD
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Biotechnology Partnership and Development (BioPAD) is one of South Africa's regional innovation centres. It was created under the auspices of the Department of Science and Technology and its National Biotechnology Strategy. This strategy is aimed at establishing a sustainable biotechnology industry in South Africa. BioPAD has several initiatives in mining, environmental and industrial biotechnology. It is promoting the exploitation of micro-organisms and enzymes. Some of the examples of research and commercialization groups in BioPAD include: Rhodes University Biotechnology Group, University of the Free State Microbiology Group, CSIR Bio/Chemtek and Environmentek Groups, Mintek Biotechnology Group, BHP Billiton etc. Mintek, together with its joint-venture partner BacTech Environment Corporation, offers the full range of services required for the evaluation and commercial implementation of bacterial leaching processes, including bacterial cultures, test-work and consulting, piloting, flow-sheet design, and plant commissioning for gold and base-metal projects. The CSIR Bio/Chemtek biotechnology group has equipped laboratories for biocatalysis, process research and development as well as structural biology. The organization has pilot facilities of up to 2000 l and semi-commercial Imbiza multi-purpose facility. BioPAD will endeavour to support the development and use of key technologies such as microbial genomics, proteomics and bioinformatics to enhance South Africa's competitiveness in mining, environment and industrial manufacturing industries. Development of innovative bioprocesses for environmental remediation and beneficiation of agricultural wastes will also be promoted.

To promote the development of local technology, African countries need to review the existing incentive structures. A range of structures suitable for creating and sustaining enterprises exists, from taxation regimes and market-based instruments to consumption policies and sources of change in the national system of innovation. Much of the constraints to small and medium size business development are due to market failures and imperfect information. Governments can help by instituting measures that lead to the creation and expansion of enterprise, including incentives that promote the use of intellectual capital in economic transformation.[129] Examples of such measures include:

(a) promoting the establishment of business and technology incubators, business development services and technology parks;
(b) fostering the development of the micro-credit sector;
(c) building exclusive economic zones, permitting participating firms to acquire their imported inputs duty-free in exchange for an obligation to export; and

(d) forging production networks, giving small and medium enterprises access to skills, educated labour, and pooled business services.

In order to commercialize biotechnology and encourage innovations in the area, there is need to foster partnerships at the local, regional and international levels. Public and private research and development co-operation is needed to address key challenges which include:

- The priority needs of the poor
- The market demands for improved food quality and safety
- The need for new products and processes that have significant commercial value and can lead to economic development and advancement.

Differences in incentives, concerns about transactions costs and lack of information can limit immediate development of public-private partnerships[130] but there are success stories such as the African Agricultural Technology Foundation and the Global Alliance for Livestock Vaccines (GALV)– a partnership between large pharmaceutical companies and donors – is making new livestock disease technology available to developing countries. The GALV aims to produce vaccines to prevent deaths of one in five animals each year within the next 10 years, which will benefit the over 600 million people who depend on livestock for their livelihoods.[131]

Small and medium enterprises (SMEs) should lead the development of new opportunities and the use of technology. Africa policy makers need to develop, apply and emphasise the important role of engineering, technology and SME development in wealth creation and sustainable social and economic development. Specifically, they should support business and technology incubators, exclusive economic zones and production networks. Furthermore, skills upgrading through business education and industrial training are paramount.

Virtually all of the few African success stories in agricultural development are associated with well-functioning output markets.[132] Unreliable grain markets lock many farmers into inefficiently producing as much of their own grain needs as possible, rather than innovating with new crops.[133] Effective *input supply systems* are essential, particularly when technological change or advance depends on purchased inputs. Establishing the systems to provide those inputs is, however, one of the major challenges for many technologies.[134] Advances in biotechnology will require functional market infrastructure to be useful to economic development.

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Box 17*:* Increasing maize yields of smallholder farmers in East Africa

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Maize is the most important food crop in Kenya, providing on average 44% of calorie intake. However, farmers are unable to increase their productivity unless the problems of plant diseases, reducing soil fertility and increasing soil acidity are overcome. DfID research under the renewable natural resources research strategy has benefited not just poor maize farmers, who are able to produce more maize, beans and vegetables for less work, but also village and small town level agricultural input suppliers – providing important insights into building relationships between different stakeholders.

Conventionally, fertiliser is retailed in large bags, which are too expensive for the risk-averse farmer. A Kenyan organisation, Farm Input Promotions Africa, packages fertiliser in small bags and provides a small pack of disease-resistant certified seed free of charge. Since the research began in January 2003, over 200,000 1 kg bags of fertiliser have been sold in the project area, and more than 60,000 free small packs of maize seed have been provided by the seed companies. Yield increases of up to 150% have been achieved through the use of fertiliser and improved maize seed. A reduction in the use of herbicides has also reduced the cost of production by 50%.

Through the research, people who supply farm inputs such as seed and fertiliser have been trained in the identification and control of maize streak virus. Private firm Western Seed Company has vastly expanded its operation in the districts covered by the project, and thousands of farmers are benefiting from improved crop yields, even when the rain is below average.

The research provided solutions to technical production problems, but more importantly, it helped to bring together public- and private-sector organisations with farming communities to increase the supply of fertiliser and virus-resistant seed and ensure sustainability.[135]

Africa has very little private sector investment and development, impeding the commercialization capacity required to translate biotechnology research into new products and emerging enterprises. To improve commercialization and business capacity, Africa needs to: (1) foster R&D cooperative partnerships at the local, regional and international levels; (2) create policy instruments that enable business incubation and development; (3) develop functional market infrastructure for economic development; and (4) stress the role of technology in general and biotechnology in particular for SME development policy.

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Regulating Technology

Pre-emptive laws that focus on risks can hamper Africa's capacity to harness emerging technologies to meet its needs. Focusing on technological risks can overshadow the possible benefits of an emerging technology, which are often difficult to predict. Strict, risk-focused regulatory regimes may hinder the technology transfer, adoption, development, and potential benefits of emerging biotechnologies. Biosafety policies and laws need to be harmonized using national practices as a basis. The idea locus for such harmonization should be the RECs. On the whole, adopting laws that pre-empt technological opportunities should be pursued with caution.

General technological capacity building is critical for building a regulatory regime. Countries that have capacity in biotechnology research are also in a better position to design and implement regulatory systems. Managing technological uncertainty will require greater investment in innovative activities at the scientific and institutional levels. Biotechnology R&D research can enhance familiarity with biotechnologies (and their products) and contribute to informed biosafety decision-making through risk assessment studies.

Countries that have advanced in biotechnology are adopting the co-evolutionary approach where safety management goes hand in hand with the development of the technology itself. The way forward is to adopt a dynamic approach that involves the harmonization of regulatory practices at a regional level based on practical experiences. Regulatory frameworks must ensure an adequate level of protection and provide sufficient flexibility in recognition of likely advances in scientific understanding. And regulatory burdens should be streamlined to provide biotechnology firms, as much as possible, with a predictable regulatory environment that continues to encourage and foster scientific technological innovation while assuring the protection of public health and welfare.

Strict, risk-focused regulatory regimes may hinder the technology transfer, adoption, development, and potential benefits of emerging biotechnologies. Africa must adopt the co-evolutionary approach where safety management goes hand in hand with the development of the technology itself so that the continent's freedom to innovate is safeguarded and enhanced.

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Societal Capabilities

To build credibility and social acceptance of biotechnology, especially agricultural biotechnology, and to ensure that this technology contributes to addressing the pressing social and economic needs of Africa, a new partnership is needed between all stakeholders – between public and private research, between scientists and citizens and policy makers and between researchers and the private sector. Such partnerships should be based on the following principles:

(a) Open dialogue on biotechnologies, risks, opportunities and benefits (science-based evaluation procedures that objectively determine the benefits and risks of each GM organism on a case by case basis; well functioning regulatory systems are the only way to regain public confidence in food safety.)
(b) Decisions should be based on evidence.
(c) Equitable sharing of benefits.
(d) Focusing on long term interests of the public.
(e) Facilitating access to information.
(f) Commitment to the general public benefits and a long term perspective rather than narrow and immediate gains for any single group.

Public awareness of and confidence in biotechnology is one of the factors that will influence the extent to which African countries individually and/or collectively adopt the technology. Lack of awareness and misinformed perceptions of the technology—its nature, benefits and risks—have made it difficult for countries to individually and collectively set priorities and proactively exploit economic and technical opportunities offered by modern biotechnology. At the moment the African public is confronted by information and opinions from industry, governments, scientists, environmental activists, and media. Few countries have designed and implement programmes for public awareness and understanding of biotechnology. Experiences on and skills for conducting public awareness and understanding surveys are limited on the continent as a whole.

With the ongoing debate on GM crops, confusing counter claims from pro- and anti-GM activists, and often passive reactions by African governments, the public is likely to lose confidence in modern biotechnology and its economic opportunities. What are required in the region today are programmes and processes that will inform the public and legitimately bring the voices of the public to inform and change the focus and content of the current debate. Stakeholders such as youth, women, farmers and other social groups need to be represented in policy processes on biotechnology.

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Box 18*:* South Africa's initiative to promote public awareness of biotechnology

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In early 2003, the programme on the "Public Understanding of Biotechnology" (PUB), was launched through the South African Agency of Science and Technology Advancement (SAASTA), which is part of the National Research Foundation (NRF). The overall aim of the PUB is to promote a clear understanding of the potential of biotechnology and to ensure a broad public awareness, to stimulate dialogue and debate on biotechnology's current and potential future applications, including genetic modification. The target audience includes all facets of society with emphasis on consumers, educators and learners (www.pub.ac.za). A recently released study, commissioned by PUB, found that South Africans' knowledge and understanding of biotechnology is limited. In reply to the question, "What do you think when you hear the word biotechnology," 82% of the 7,000 respondents indicated that they had no idea.

The AU Commission and NEPAD can also play a major role in promoting awareness of and understanding of modern biotechnology among civic bodies, political institutions and the general public. With technical support of institutions such as the United Nations Economic Commission for Africa (UNECA), AU Commission and NEPAD can develop and launch continental programmes for building awareness and understanding. They can also promote the conduct of exercises to assess public awareness and perceptions of the technology. Such assessments would be accompanied by organized activities to provide the public with reliable and adequate information on the nature of modern biotechnology and its products.

APB proposes the use of prizes to accelerate agricultural innovation in Africa. Awarding prizes in proportion to the measured gains from adoption of new farming techniques would help focus innovators' attention on adoption and impact and leverage funds from other sources to help meet farmers' needs. Prize payments would be made to public research laboratories, NGOs and input supply companies involved in the development and dissemination of improved crop varieties or other agricultural innovations. To earn these payments, innovators would submit data from field experiments and farm surveys documenting the value of technology adoption not captured through input sales. A prize secretariat would spot-check the data, compute estimated economic gains, and award each applicant the corresponding fraction of available funds. Prize payments would reward and recognize the productivity gains generated by new technology, leveraging other donors' investments in R&D and farmers' investments in technology adoption. The immediate impact of prize payments would be to accelerate the flow of innovations through the existing technology pipeline onto farmers' fields.

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Box 19*:* Advance Market Commitments as a R&D funding mechanism[136]

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Private biotechnology and pharmaceutical firms are unlikely to invest in R&D on products which they expect to be unable to sell at prices that would cover their risk-adjusted costs. Low expected prices for products such as an HIV vaccine reflect both the poverty of the relevant populations as well as severe distortions in the markets for these diseases.

One proposal to incentivise private sector R&D investments in products for diseases concentrated in poor countries is for sponsors (rich country governments, private foundations, or international organizations such as the World Bank) to undertake "advance purchase commitments" for desired products, such as an HIV vaccine, with the goal of creating market incentives for firms to develop needed vaccines. In advance purchase commitments, sponsors commit (in advance of product development and licensure) to fully or partially finance purchases of vaccines for poor countries at a pre-specified price. A program sponsor or coalition of sponsors that potential investors in R&D would find credible (i.e. sponsors that are financially solvent and are thought to be unlikely to renege on a commitment) would sign a contract underwriting a guaranteed price for the supplier. Poor countries would decide whether to buy a product at a low and affordable price (say, $1 per treatment), and sponsors would guarantee to top-up to a guaranteed price (say, $15 per treatment) – thus providing market returns for the developer which are comparable to other, average-revenue pharmaceutical products. Once the full number of treatments is purchased at the guaranteed price, the supplier would commit to selling further treatments at an affordable price in the long-term. The sponsors could retain the right to seek alternative suppliers at the end of the guaranteed price contract period. Although not part of the contract, there would be nothing to stop the original sponsors or other donors from covering the $1 price on behalf of poor countries at the time of purchase.

The idea of advance purchase commitments for vaccines has recently been gaining political momentum. In 2004 the U.K. government announced they would work in cooperation with other donors on entering into an advance purchase commitment for a malaria vaccine. In December of 2005 the G-7 finance ministers announced an agreement to work with others on developing a pilot advance purchase commitment during the 2006 calendar year.[137]

The use of advance market commitments to encourage R&D in diseases and agricultural commodities of poor countries (box 29) is also recommended.

Public awareness of and confidence in biotechnology is one of the factors that will influence the extent to which African countries individually and/or collectively adopt the technology. Conversely, lack of awareness and misinformed perceptions of the technology—its nature, benefits and risks—make it difficult for African countries to individually and collectively set priorities and proactively exploit economic and technical opportunities offered by modern

biotechnology. New stakeholder partnerships, awareness campaigns, and innovation competitions can be created to facilitate public understanding and education on issues of biotechnology.
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Financial Capabilities

Limited availability of funding is one of the major factors that hinder the development of science and technology in general and biotechnology, in particular. Reliable financial support need to be mobilized in order for Africa to participate effectively on the biotechnology platform. This will require governments committing more resources to research and development and reaching out to some other funding avenues that have worked well in other regions but are yet to be fully exploited in Africa. The Panel upholds the recommendation by the Inter-Academy Panel for Global Fund to support centres of excellence which are regional in nature or can evolve to perform regional functions. The process of establishing centres of excellence in biosciences has already been started by NEPAD/AU; these should be supported so that they can champion biotechnology research and development.

Biotechnology being a highly competitive industry requires national initiatives but will succeed through regional cooperation given the high capital investment needed to improve and modernize the physical infrastructure and have adequately trained and highly skilled personnel. Scientists involved in research and development or working in academia have a responsibility to advise policy makers and demonstrate through their work and publications that the public and private investments in S&T and biotechnology can contribute to wealth creation and solving societal problems. Scientists need to build a new contract with civil society, government and private sector and lead the development of biotechnology in Africa.

The establishment of regional biotechnology programmes and institutions needs to be complemented with the creation of appropriate mechanisms to finance R&D. Current funding of biotechnology research is still too low to enable African countries to effectively exploit its economic opportunities. For example, an assessment by Falconi in 1999 showed that Indonesia's total expenditures on biotechnology research, for the 1985-96, was US$ 18.7 million while Kenya spent just about $3.0 million.[138] Nigeria and South Africa are increasing their financial investment in biotechnology. Nigeria's Federal Government now provides the National Biotechnology Development Agency with an average of US$ 263 million per year for the next three years as a start-up grant. South Africa's new biotechnology strategy commits more than US$ 300 million per year from government to finance a variety of biotechnology initiatives.

Other countries of the region need to invest more in biotechnology. Some may wish to create special funding mechanisms (possibly National Biotechnology Funds (NBFs) for R&D). Such mechanisms would mobilize domestic and international public and private finance to support specific priority research and innovation activities that target productivity improvement. Many countries have used a variety of models, including independent funds such as the National Science Foundation in the US and the National Research Fund of South Africa. Others have focused on ensuring that development needs guide research funding and, as such, have created specific funding mechanisms under development planning ministries. While this approach is not a substitute for funding to other activities, it distinguishes between measures designed to link technology to the economy from those aimed at creating new knowledge for general learning. What is critical, however, is to design appropriate institutional arrangements and supporting funding mechanisms that bring knowledge to bear on development.

The African Ministers of Science and Technology at their second conference held in Dakar Senegal agreed on the following mechanisms to ensure that funding for science and technology is available:

(a) Substantial increase in national R&D budgets—requiring each country to allocate at least 1% of its GDP to R&D. The African Peer Review Mechanism (APRM) would be used to assess progress towards meeting the target. Each country would then be required to contribute at least 5% of its R&D budget to a funding facility catering for regional and continental R&D programmes.

(b) A distinct African funding scheme or facility should be established. This would be resourced through (a) annual assessed contributions by African countries based on agreed upon procedures (b) consortia of bilateral and multilateral agencies convened by AMCOST. (c) NEPAD Business Group.

(c) The African funding scheme or facility would be created as partnership with the African Development Bank, the African Capacity Building Foundation and the World Bank as well as with other donors. Flexibility should be created so that donors can also fund specific projects and programmes of the networks.

(d) Countries that are hosting local innovation areas and nodes of the networks would be required to make specified contributions.

Creating incentives for domestic mobilization of financial resources, as a basis for leveraging external support would be essential. Other innovations in taxation, already widespread around the world, involve industry-wide levies to fund research, like in Malaysia (box 20). Kenya levies cess on its tea, coffee, and sugar industries to support industry-specific research. These initiatives could be restructured to create and R&D funding pool to cover common areas in biotechnology development.

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Box 20: Malaysia uses a cess mechanism to fund research[139]

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One way to target sector-specific technological needs is to introduce an industry-wide cess. Malaysia has imposed cesses on rubber, palm oil, and timber to fund the Rubber Research Institute, the Palm Oil Research Institute, and the Forestry Research Institute. A cess on tea helps fund research on and marketing of tea in Sri Lanka. Hong Kong (China), Malaysia, and Singapore have all established construction industry development boards. Funding for the boards comes from a compulsory cess on all construction contracts. The revenue is used to build capacity and promote innovations in construction materials and techniques.

A Malaysian project involving government, academia, and industry is the Housing Research Centre at the University Putra Malaysia. Using locally developed building systems and local materials, the centre has built experimental houses that are in the process of commercialization. The centre's Putra Block, an industrial building system, is patented in the United Kingdom. Malaysia won a gold medal for the system at the International Innovation Expo in Geneva.

Cess on imports could also spur innovation, although the WTO may object to them. To encourage stock markets to contribute to sustainable development in developing countries, a cess of 0.05 or 0.1 percent of the turnover of stock markets could be imposed and used to establish a global fund for sustainable development.

Reforming tax laws is an essential element in this strategy. Private individuals and corporations need targeted tax incentives to contribute to research funds and other technology-related charitable activities. This instrument for supporting public welfare activities is now widely used in developing countries. It arises partly because of the lack of experience in managing charitable organizations and partly because of the reluctance of finance ministries to grant tax exemptions fearing erosion of their revenue base. However, it can be argued that areas such as education, health, and environmental management could benefit from the local generation of revenue where specific exemptions are provided by law to encourage charitable trusts.[140] The enactment of a *foundation law* that provides tax and other incentives to contributions to public interest activities, such as research, education, health and cultural development would promote social welfare in general and economic growth in particular.

Other countries are looking into using *national lotteries* as a source of funding for technological development. Other initiatives could simply involve restructuring and redefining public expenditure. By integrating R&D into infrastructure development, for example, African governments could relax the public expenditure constraints imposed by sectoral budgetary caps. (Brazilian scientists proposed a similar approach to their Government as a framework for negotiations with the IMF.) Such a strategy, if pursued, has the potential to unlock substantial funds for biotechnology R&D activities.

Appropriate financial institutional infrastructure is also important in fostering business development and technological innovation. The record of financial institutions in this field has been generally poor in developing countries. Banking and financial reforms would allow them to help promote technological innovation. Capital markets, such as venture capital, have played a critical role in creating SMEs in developed countries. Other than arranging funding, venture capitalists also help groom business start-ups into competitive and profitable firms. Bringing venture capital into African countries would help create new businesses and improve their sustainability.

Limited availability of funding is one of the major factors that hinder the development of science and technology in general and biotechnology, in particular.The following mechanisms can be instituted to increase the available funding for biotechnology R&D in Africa: (1) substantially increased national R&D budgets; (2) special funding mechanisms, possibly innovation funds and provided through a variety of ways including challenge approaches similar to those used by the Gates Foundation; (3) specific funding mechanisms under development planning ministries; (4) distinct African funding schemes or facilities; (5) reformed tax law (i.e., foundation laws and industry-wide levies); and (6) national lotteries.

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Chapter 5: Outlining Strategic Considerations

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Developing Africa's Regional Innovation Communities

Most of the R&D capacity in Africa is scattered across a wide range of independent research institutions that are not organized around specific technology missions or research programs. As a result, resources are not effectively utilized. One way to address this challenge is to pool resources to pursue research in priority areas identified by national governments. African countries should emphasize the formation of regional innovation communities to concentrate capacity. They need to evolve with strong public-private partnership to pass on products of R&D to end-users. More so, the regional research centres should foster strong and effective collaboration involving local communities, businesses, universities, Governments, the African Diaspora, and international partners.

Regionalism offers platforms on which scientifically and technologically weak countries articulate their demand for technology, innovation policy and related institutional adjustments. If carefully configured and governed, it provides a good foundation for restoring and enlarging Africa's confidence in its own abilities to generate and manage knowledge for economic change and human development.

Regional cooperation in science and technology can take various forms, including joint science projects, sharing of information, conferences, building and sharing joint laboratories, setting common standards for R&D, and exchange of expertise. Its advantages for African countries include:

(a) access to new knowledge, foreign skills and training opportunities that may not be available at the national level
(b) access to large and often expensive research facilities, including laboratories and libraries
(c) avoiding the costs of duplication of research
(d) enrichment of political and social relations between countries
(e) opportunities to establish multidisciplinary research activities and teams
(f) favourable basis for international funding
(g) building or strengthening domestic R&D institutions.
(h) broadening the R&D scope through market expansion.

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Box 21: The Pan African Rinderpest Campaign (PARC)

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The African Union (AU) launched the Pan African Rinderpest Campaign (PARC) in 1986 to completely eradicate Rinderpest disease on the continent through technical cooperation and coordination of national projects in 35 participating countries. PARC coordinates external funding, identification of national needs, border harmonization dialogue and provides technical support. Although a vaccine existed since 1920, the lack of regional co-ordination resulted in failure to eradicate the disease. Through PARC programs, African laboratories were responsible for vaccine production, quality control, sero-surveillance and disease diagnosis. In addition, PARC had 4 regional emergency vaccine banks, two PARC/OAU regional coordination centres and centres for vaccine quality control and disease diagnosis. It is estimated that 45 million cattle were vaccinated annually. PARC programs also helped countries build technical expertise in disease surveillance and reporting. One element that made PARC successful was its communications unit that helped sensitize farmers, veterinary experts, policy makers and donors. The EU, as the main donor, and several international agencies, institutions and individuals contributed to PARC.[141]

The evolution of regional biotechnology innovation systems in Africa will be based on the growth of regional and continental networks of institutions for R&D and commercialization.

It may also involve the establishment of regional R&D and innovation communities. Encouraging such networks as BIO-EARN to focus on regional economic priorities and extending their focus on non-agricultural areas such as industrial and environmental biotechnology would be one option of creating networked institutional arrangements. This may, at least in the short-run, be cheaper than creating brand new centres or institutions.
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Box 22: Southeast Asian Regional Training Centre in Biotechnology
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In 2004, the Southeast Asian Regional Training Centre in Biotechnology was established by collaborating research institutes in the Asian region and international organizations engaged in capacity building. It was agreed that such a Regional Training Centre in Biotechnology is needed and that Thailand, through its National Centre for Genetic Engineering and Biotechnology (BIOTEC) was in a good position to spearhead this initiative. At this stage, the Regional Training Centre is operated as an independent program under BIOTEC, to allow flexibility and ease in forming partnerships with various cooperative agencies. In addition to organizing its own training program, the Regional Training Centre would serves as a strategic partner to other organizations to co-organize capacity building activities.

The long term goal would be for each of the five regional economic bodies to have a regional biotechnology research and innovation centre, or at least a network of centres similar to the one in Southeast Asia (box 23). One possible scenario is the development of biotechnology specializations for each regional innovation community. For example, Northern Africa can specialize in Pharmaceutical and Medical Biotechnology, Eastern Africa can focus on Animal Biotechnology, Western Africa can concentrate on Agricultural Biotechnology, and Southern Africa can dedicate its energy and resources to Industrial and Environmental Biotechnology.

Africa's regional economic communities provide a geographical and economic space for technological integration, cooperation, and capacity-building. Regional economic communities should begin to determine potential opportunities for biotechnology specialization and foster regional networking of biotechnology centres for R&D related to this regional specialization.
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Local Innovation Areas

Table 10: Potential Projects for East African Local Innovation Area
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Project	**Description**
Livestock Vaccine and Diagnostic Kits	Produce cutting-edge products such as diagnostics kits based on animal and plant diseases that are unique to the tropics, and which can be exported to other countries to earn foreign exchange.
Drought-Tolerant, Disease Resistant Crop Initiative	Coalition of private companies and public sector entities can develop disease-resistant, drought-tolerant world crops, making East Africa a one-stop-shop for agricultural biotechnological innovation.
Artemesia Annua	Grow, develop processes for extracting artemesinin active ingredient from plant, and/or manufacture whole plant artemesia tablets for sale and distribution to regional markets and international aid and multilateral agencies.
Pyrethrum-Impregnated Nets	Develop processes for manufacture of pyrethrum-impregnated nets as Long-Life Insecticidal Nets for sale and distribution to regional markets and international aid and multilateral agencies (WHO).
Wildlife Biodiversity and Conservation Project	Work with neighbours to use the region's wildlife resources to become world leaders in animal biotechnology. Sustainably develop commercial products from natural sources (arthropods, plants, and microorganisms) that can generate income to stimulate conservation and management of biodiversity in East Africa.

International Collaboration

Most African institutions work in isolation without research and development partners. The African institutions need to find areas of commonalities that would enhance collaboration in crops, genes, and regulatory regimes, among others. Private firms and public research institutions need to share information on these areas of commonality and complementarities in order to forge collaboration. Information sharing is particularly important for south-south collaboration arrangements, a partnership that is currently weak or does not exist in Africa. This collaboration will provide one of the ways of strengthening inter-institutional research and experiences in biotechnology.

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International partnerships

Africa's regional innovation communities should share with neighbouring countries the results of their scientific and technological cooperation with the industrialized nations and the lessons learned from the latter in nurturing young scientists and engineers. Developed nations themselves could directly impart such knowledge with efforts of their own, such as programs that establish temporary adjunct-faculty/research positions at some of their universities and laboratories for scientists and engineers from other countries, particularly the developing ones. A good precedent is a German program, in operation over the past decade, that placed Russian researchers in German institutes for three-month positions (at German salaries), whereupon they returned home. This experience, which put them at the forefront of research, could then be of benefit to their Russian colleagues as well.[142]

A prominent example of such an effort that is graduate-student oriented, of longer duration, and located wholly within southern Africa is the Research Initiative of the University Science, Humanities, and Engineering Partnerships in Africa (USHEPiA) – a network of eight universities in Sub-Saharan Africa. In part to stem the brain drain and promote 'brain circulation' within the region, USHEPiA has identified and formulated a number of significant multi-institutional and multidisciplinary project proposals addressing HIV/AIDS, tuberculosis, and malaria, including the development of appropriate drugs using African natural resources. Participating institutions in the anticipated network, focusing on infectious diseases, would together offer world-class facilities and expertise for the training and deployment of health-science researchers. The network would be coordinated by the University of Cape Town's Institute of Infectious Disease and Molecular Medicine.[143]

USHEPiA, and other partnerships like it – the African Economic Research Consortium, for example – focus on knowledge and how best to generate, share, and apply it to local development problems. In addition, these programs can make significant contributions to the global knowledge pool, illustrating the notion that knowledge needs to flow in all directions, including from developing nations to industrialized nations. The wealth of international expertise, when combined with strengthened local research and innovation systems, can establish a sustainable path to closing both global and local knowledge divides.

Such efforts can be complemented, and much facilitated, by the tools of new information and communications technology, which has put the S&T community in a better position than ever to make international cooperation a practical reality. In particular, scientists and engineers located anywhere can be networked for exchanging information and pursuing joint research.

Information and communications technology can also play an important role in developing human resources through such institutions as virtual universities. In addition to providing mechanisms like distance-learning and video conferencing, they enable 'anytime, anywhere' access.[144]

Special programs and support from industrialized nations and the S&T-proficient nations are especially indicated for scientists and researchers working in politically or economically troubled and war-torn areas of the globe. These professionals, often isolated from the rest of the worldwide science community, are able to provide, by virtue of their scientific training and values, local voices for modernization and science-based public policy.[145]

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Harnessing the Potential of the African Diaspora

Another strategy for mobilizing human resources and building critical masses is through the conscious use of the African Diaspora. The African Diaspora is a rich source of scientific and technical skills in modern biotechnology. There are African scientists and technicians based in the USA, Europe and Asia and working on functional genomics, bioethics, science policy, and a range of other areas relevant to modern biotechnology. It is estimated that at least 30 percent of all highly trained Africans reside outside the continent.[146] Some have organized themselves into networks and associations to support the strengthening of scientific research in their home countries and the continent as a whole.

Migration of highly skilled workers from global south to global north has not spared Africa and is therefore one of the contributing factors to economic and social disparities. It is important to address the so-called "brain drain" issue. The enormous gaps existing between the north and the south as well as the demographic trends that show an aging north unable to provide enough young people for the needs of its growing, technology driven economy, all imply that brain drain will continue. Instead of the South investing in fighting this trend, they should expand training opportunities for young people in the popular disciplines and encourage the advanced research universities of the North to bear more of the training burden, through arrangements such as sandwich programs and enhanced fellowships. Developing countries should develop effective monitoring and foresight of international knowledge trends and migration to tune their national training strategies.

Significant experiments are under way around the world to make effective use of the Diaspora. The Swiss government has converted part of its consulate in Cambridge (Massachusetts, USA) into a focal point for interactions between Swiss experts in the USA and their counterparts at home. The Swiss House was created in recognition of the importance of the area as the world's leading knowledge centre, especially in the life sciences. In addition to Harvard University and Massachusetts Institute of Technology (MIT), the Boston area is home to more than 50 other colleges and universities and a cluster of biotechnology activities.

In another innovative example, the National University of Singapore has established a college at the University of Pennsylvania to focus on biotechnology and entrepreneurship. The complementary Singapore-Philadelphia Innovators' Network serves as a channel and link for entrepreneurs, investors and advisers in the Greater Philadelphia region and Singapore. The organisation seeks to create opportunities for collaboration and partnerships in the area. India is introducing a number of policy measures – including granting dual citizenship to Indians in countries of strategic interest – aimed at strengthening the role of the Diaspora in national development. Such approaches can be adopted by other developing countries, where the need to forge international technology partnerships may be even higher. The old-fashioned metaphor of the “brain drain” should to be replaced by a new view of “global knowledge flows”.

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Box 23: Can Skilled Diasporas have Impact on Development? [147]

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Advances in telecommunications combined with diminishing air travel costs have provided highly skilled workers the opportunity to become transnational citizens by allowing them to connect and contribute to businesses and academic centres throughout the world. The emergence and increasing importance of scientific Diaspora Knowledge Networks (DKNs) and migrant remittances is redefining opinions about “brain drain”.

One of the most studied examples in which transnational communities have had a strong impact on the development of their home country is found within the Asian-American networks linking the Silicon Valley with the Hsinchu region of Taiwan. Asian-American engineers, who built social and economic bridges linking the two economies, were instrumental to the success of Taiwan’s ICT sector in the 1980’s and 1990’s. This skilled immigrant community originated from a “brain drain” of Taiwanese engineering students seeking graduate training in the USA. Specific sets of circumstances allowed them to contribute to Taiwan’s development, including: 1) the explosive growth of a new technology sector in Silicon Valley that harnessed their skills; 2) the formation of professional associations which provided role models and assisted in the advancement of individuals within the community as a result of a sense of personal and professional exclusion within Silicon Valley; 3) a high spirit of entrepreneurship within this community, and 4) an active initiative by the Taiwan government to promote the ICT sector and a proactive engagement of its overseas engineers in developing strategies to promote private sector growth in the Hsinchu region.

Further examples outside of ICT highlight the capacity of Diasporas to influence their countries’ development. For instance, the Indian-American community plays a role in the improvement of Indian hospitals through sabbatical residencies. Other approaches include organizing annual seminars, in collaboration with home country counterpart organizations, providing consultative services to the home country government, providing technology expertise through license agreements, assuming top managerial positions in their home country, mentoring of start-up managers and providing angel investments, and development of Diaspora business networks.

The Colombian *Red Caldas* network, one of the first networks to have emerged as an autonomously organized group of expatriate scientists, aims to build the Colombian S&T communities and link them to their international counterparts through professional contacts, conferences, seminars, and other knowledge-sharing strategies. About 41 expatriate organizations have emerged so far based on this model, with internet sites meant as channels for the Diaspora to identify and engage in the development of their home countries. In their in-depth survey published in 2003, Barré et. al concluded that “the large and increasing number of highly skilled migrants, their tendency to organize spontaneously, and the development of ICT combine to produce a situation conducive to the formation of S&T Diasporas.”[148]

Special outreach and support programs should be promoted by the S&T community for assuring gender and diversity. The developing countries should try to retain talent in their own institutions, within their own borders, by such measures as providing, on a temporary basis, special working conditions for our best talents (whether formed abroad or at home), including income supplements and adequate research support.

In addition, the Governments and the national S&T community should build ties with expatriate scientists, doctors and engineers, especially those who are working in industrialized countries. There is need to create specific programs that would tap into the Diaspora’s knowledge, skills, management abilities, investment possibilities, and networks. This will require an attitude shift in the countries of origin, whereby the presence of the Diaspora in the advanced countries is seen as the starting point for bridge building. Some of the deliberate efforts that would attract contribution from the Diaspora include:

(a) allowing dual citizenship,
(b) creating visiting professorships in African institutions that can be filled for short times,

(c) formalizing exchange of professors between universities and research centres in African and advanced research institutes,
(d) encouraging the Diaspora to participate in consultancies paid for by external agencies,
(e) facilitation of travel of the African Diaspora to African countries other than the country of origin
(f) reducing bureaucratic obstacles to the investment of the Diaspora in their countries of origin, including increased transparency and predictability
(g) creating data bases on the Diaspora in the various missions of the African countries abroad, and share and pool such data on an Africa-wide basis with regional sub-groupings
(h) developed countries that have received the immigrants should have their development agencies make a special effort to mobilize the Diasporas in their development efforts, possibly creating specialized agencies for such efforts.

The NEPAD/African Biosciences Initiative offers opportunities to harness and use scientific and technical expertise of the African Diaspora to engage in cutting-edge research on the continent. The network of laboratories that are being designated as hubs and equipped with modern infrastructure should become the loci of attracting the Diaspora and providing conditions that are conducive for research and innovation. Under the Initiative a special mobility trust fund should be created to provide financial resources to cover travel and research costs of African scientists who are willing to spend time at the hubs to work on identified regional priority projects.

The international community, other developing nations, and the African Diaspora have the potential to play a critical collaborative role in Africa's economic development and technological capacity building. African Regional Innovation Communities should facilitate North-South and South-South collaborations as well as mobilize the knowledge network of its Diaspora for "thickening" emerging Regional Innovation Communities and Local Innovation Areas.

Chapter 6: Governing Biotechnology

In terms of public intervention, regional, national, other policy actors and organizations can shape the development and dynamics of regional innovation systems.[149] Looking at the innovation process in the broadest sense, it is essential to design political initiatives that adequately foster learning processes. Governance should not only concern itself with investments in R&D and the technological aspects of innovation alone, but it should also deal with the organisational, financial, educational and commercial dimensions of innovation.[150] Policy intervention, formulation, and implementation should be rethought of as the result of intensive communication, and close interaction and consensus building with all actors in the innovation system. Governance structures, instead of directly intervening in innovation activities, focus on stimulating, intermediating, brokering, and promoting regional dialogue and building up social capital.[151] Thus, regional governance structures can provide the central stimulus to spark the transition to a learning region.[152]

General technological capacity building is critical for building a regulatory regime. Countries that have capacity in biotechnology research are also in a better position to design and implement regulatory systems. Managing technological uncertainty will require greater investment in innovative activities at the scientific and institutional levels. Biotechnology R&D research can enhance familiarity with biotechnologies (and their products) and contribute to informed biosafety decision-making through risk assessment studies.

Countries that have advanced in biotechnology are adopting the co-evolutionary approach where safety management goes hand in hand with the development of the technology itself. The way forward is to adopt a dynamic approach that involves the harmonization of regulatory practices at a regional level based on practical experiences. Regulatory frameworks must ensure an adequate level of protection and provide sufficient flexibility in recognition of likely advances in scientific understanding. And regulatory burdens should be streamlined to provide biotechnology firms, as much as possible, with a predictable regulatory environment that continues to encourage and foster scientific technological innovation while assuring the protection of public health and welfare.

Currently, it is difficult to determine the legitimate loci of biotechnology decision-making in many African countries. Due to the cross-cutting and interdisciplinary nature of biotechnology, there is need for co-ordination and co-operation between key ministries (e.g. Environment, Agriculture, Health, Industry, Planning, Finance, Trade, Foreign Affairs,) administrations, industries, legal bodies and research institutions. What is required is the review and determination of appropriate decision-making mechanisms. Such mechanisms should have representation from all stakeholders including farmers, consumers, environmentalists and religious bodies. Facilities for information sharing, public-private partnerships, IPR, market studies and foresight analysis are also needed to support the knowledge-based environment that is required for a thriving biotechnology industrial base.

The development and application of biotechnology are being regulated by a wide range of instruments and structures at national, regional and international levels. At national level some countries are experimenting with such instruments as biosafety frameworks, intellectual property laws, ethical guidelines and food safety standards to regulate not just the commercialization of products of the technology but related R&D activities as well. International guidelines and protocols are being developed and promoted to govern biotechnology. These include the Cartagena Protocol on Biosafety and Codex Alimentarius. These national and international regulatory regimes will determine the evolution of regional biotechnology innovation systems in Africa. Diversity of national regulatory approaches within Africa and between the continent and the rest of the world will influence regional biotechnology R&D and related technological innovation.

This chapter explores specific governance issues and related institutional arrangements that will influence regional biotechnology R&D and applications for economic development. It provides an overview of international and regional governance approaches and their implications for African development. Emphasis is placed on specific issues and approaches that should be considered by African countries in their efforts to establish shared biotechnology R&D and related technology development platforms.

Scientific Basis for Policy-Making and Governance Mechanisms

Scientific evidence regarding the risks and benefits of GM crops concludes that there is no compelling evidence of harm from the consumption of foods and food products containing GM components. The analysis of data from countries where GM crops have been grown for ten years indicates that there is no scientific evidence of harm to the environment where GM crops are grown. The benefits of growing GM crops include (1) a reduction in the use of harmful pesticides (with *Bt*-cotton in China); (2) economic benefits to farmers, including smallholder farmers (*Bt*-cotton farmers in South Africa). While there is evidence of benefits to consumers, at this stage more data is required.

There are a large number of lobby groups presenting arguments against GM crops. On the whole, these arguments are not based on objective analysis of the scientific data that has emerged in the very recent past.

The risks, benefits, socio-economic and other issues surrounding GM crops and products, socioeconomic and other issues surrounding GM crops are not the same for all GM crops and products. Each crop, product and their uses require specific analysis and consideration. Each African country will need to have access to good scientific information and advice. Some countries may have this capacity, while some may not. Scientific capacity for analysis of emerging technologies should be fostered in Africa. This can be done through regional mechanisms or Africa-wide institutions such as the African Academy of Sciences.

There is no justification for the blanket ban on the growth or use of GM crops. On the basis of scientific evidence, African countries should make their decision to develop their own varieties for GM crops.

Scientific evidence regarding the risks and benefits of GM crops concludes that there is no compelling evidence of harm from the consumption of foods and food products containing GM components. Africa must develop scientific capacity to assess biotechnology-related risks through regional and/or continental institutions or mechanisms so that all biotechnology policy is informed by science and not fear or scepticism.

Regional regulatory regimes

The current regional policy and regulatory initiatives on GMOs may be divided into two categories. The first category entails those initiatives that are being undertaken in a research context based on sub-regional research or crop networks, such as the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) and the West

African Council for Agricultural Research and Development (CORAF/WECARD). The second category entails initiatives that are based on existing sub-regions that are geo-political entities based on geographical configurations, such as Southern Africa Development Community (SADC), the Economic Community for West African States (ECOWAS) or the East African Community (EAC).

Generally, considerable efforts at policy and administrative developments in the area of transboundary movement and trade in GMOs are taking place in the context of sub-regional political entities. The most advanced in this regard seems to be SADC, which has constituted an Advisory Committee on Biotechnology and Biosafety. The Committee was launched in April 2003 with the overall mandate "to develop guidelines to safeguard Member States against potential risks in the areas of human and animal food safety, contamination of genetic resources taking into account ethical and trade-related issues including consumer concerns."[153] In August 2003, the Committee adopted, as interim measures, a set of Guidelines in a broad range of issues relating to the transboundary movement and trade in GM products. The Guidelines were approved in May 2004.[154]

The SADC Guidelines on GMOs cover four main policy areas: handling of food aid; policy and legislation; capacity building; and public awareness and participation. The guidelines, for example, require donors providing GM food aid to comply with the principle of prior informed consent and with the notification requirements set out in Article 8 of the Cartagena Protocol. The Member States also commit themselves to "develop and adopt a harmonized transit information and management system for GM food aid designed to facilitate transboundary movement in a safe and expeditious manner." The requirement for clear identification and labelling of food aid in transit is to be in accordance with national legislation and where national legislation does not exist, countries are encouraged to apply the Africa Model Law.

Regarding policy and legislation, the SADC Member States commit themselves to develop national biotechnology policies and strategies as well as expediting the process of establishing national biosafety regulatory systems. The Guidelines commit SADC sub-region to develop a harmonized policy and regulatory system. Risk assessment and testing of GM products will be done on a cases-by-case and in the environment under which it will be released.

Other sub-regional initiatives have mainly taken place in a research context, such as in the cases of ASARECA and CORAF. These initiatives largely involve research institutions, especially National Agricultural Research Organizations (NAROs), with programmes focusing on harmonization of legislation and regulations on biosafety. These initiatives are distinguishable from the geo-political initiatives because they are largely based on "moral suasion" and often lack the political and economic contexts, which are essential for the proper articulation of enforcement and compliance mechanisms. In this regard, policy and regulatory regimes based on the geo-political model promise faster progress in developing necessary policies and regulatory frameworks to regulate transboundary movement, trade and release of biotechnology products.

There is a need to develop harmonized legislation and measures based on international, continental, and individual country good practices. Development of such frameworks can lead to a co-evolution of regulatory frameworks that protect the environment and safeguard biodiversity while promoting technology development and increasing capacity to grant Africa access to the potential benefits of biotechnology while building the research infrastructure to dialectically improve risk assessment activities. The idea locus for such harmonization should be the RECs. On the whole, adopting laws that pre-empt technological opportunities should be pursued with caution.

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Considerable efforts at policy and administrative developments in the area of transboundary movement and trade in GMOs are taking place in the context of sub-regional political entities. There is a need to develop harmonized legislation and measures based on international, continental, and individual country good practices in the context of the emerging RECs. Development of such frameworks can lead to a co-evolution of regulatory frameworks and technology development.

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National Biosafety Frameworks

The emerging national policy and legal regimes for biosafety will greatly affect the transboundary movement, trade and release of genetically modified products. Over the last decade, many African countries have been engaged in reform processes to formulate national policies and laws on biotechnology and biosafety. These processes reached a climax in the late 1990s, with most countries embarking on revising existing policies and legislation or opting to formulate entirely new policies on biotechnology and legislation on biosafety.

South Africa was the first to develop a specific legislation on GMOs in Africa – the South Africa Genetically Modified Organisms Act of 1997, which became effective on December 1, 1999.[155] According to its preamble, the overall purpose of the Act is to "provide measures to promote the responsible development, production, use and application of genetically modified organisms." The Act further states that it is intended to "ensure that all activities involving the use of genetically modified organisms (including importation, production, release and distribution) shall be carried out in such a way as to limit possible harmful consequences to the environment…"

In 1998, Zimbabwe amended its Research Act[156] to bring issues of GMOs under its ambit.[157] The amended legislation established the Zimbabwe Biosafety Board as the apex regulatory body for biotechnology and biosafety. In 2000, regulations were enacted setting out the procedures for conducting GMO related research and testing of GMO products.[158] The Malawi Parliament enacted the Malawi Biosafety Act in October 2002, which makes provisions for the importation, development, production, testing, release, use and application of genetically modified organisms, and use of gene therapy in animals and humans. A host of other countries are in the process of developing their biosafety policies and legislation. The UNEP/GEF Biosafety Enabling Activities Project has been facilitating these processes. The countries most advanced in this process include Uganda, Kenya, and Cameroon, among others.

Overall, African countries need to resolve three major issues regarding national biosafety regulations. First, the current policy, legal and regulatory processes do not distinguish between transboundary movement, trade and release of GM products for R&D activities and those for seeds, food, or feed. Such a distinction is important because policies for these two types of GM products necessarily need not be similar. Indeed, countries such as Kenya, South Africa, Egypt and Zimbabwe are already advanced in the R&D activities. Their national policies and legislation are largely promotional and permissive of GM related R&D. On the other hand, several countries have adopted a precautionary approach to the importation of GM food.[159]

There is increasing concern regarding bioterrorism, especially in the technologically advanced countries. Worldwide, bio-defence has become an important component of national security. The United Nations Security Council Resolution 1540 and the Convention on Biological and Toxin Weapons aim to reduce the likelihood of misuse of biotechnology. Africa's main challenge is to find the most effective way to advance biotechnology for peaceful uses while minimizing the risks of misuse.

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Box 24: Issues for National Biosafety Policies, Legislation and Regulation

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Issue #1: International development and bilateral assistance programmes are deflecting Africa's energies into the development of biosafety policies and legislation at the national level. However, there is generally no evidence of a direct relationship between the development of national capacity in genetic engineering related and actual R&D activities on the ground. How then can African countries influence the channelling of this assistance into substantive R&D activities?

Issue #2: Should the same rules governing the importation of GMOs from outside Africa apply for the movement of GMOs between African countries? Could any distinction be considered discriminatory and contrary to the principles governing international trade?

Issue #3: Africa is losing substantial resources through technical assistance programmes because of limited African expertise in biosafety legislation on the continent. What mechanisms should be adopted to develop this expertise?

Presently, Africa lacks the technology infrastructure, in terms of skilled scientists, good practices, ethical guidelines, and collaborations to reduce the likelihood of misuse of biotechnology. Without an enlightened cadre of scientists, including social scientists, policymakers, Africa may overreact to concerns about bioterrorism, which could impede harnessing biotechnology for its development. The threat of bioterrorism is no longer in the invention of new pathogens, but the development of delivery systems (weaponisation). The security of the existing laboratory facilities against theft of existing pathogens is weak. Mechanisms for emergency preparedness against biological attacks are lacking in African countries.

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A host of African countries are in the process of developing their biosafety policies and legislation and/or reforming processes to formulate national policies and laws on biotechnology and biosafety. In addition to finalizing biosafety legislation, African countries need to make distinctions between transboundary movement, trade and release of GM products for R&D activities and those for seeds, food, or feed resolve within current policy, legal, and regulatory processes.

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Food safety and standards and International Trade Policy

Generally, food safety and food standards policies have to be considered in at least three dimensions: domestic food quality and safety; food importation; and food exports. The first dimension relates to food safety standards and legislation for local food production, handling and marketing.[160] The safety standards and legislation governing food safety and food quality cover issues of transportation, premises, facilities on food premises, storage and temperature of food, food inspection, etc. Institutional responsibilities for food safety and food quality are often shared between the ministries of health, agriculture and the national bureau of standards. However, most African countries do not have either comprehensive legislation or regulations on food safety and standards. Where these exist, there exist problems of enforcement and compliance because of weak regulatory agencies. Because of the current controversies and risk considerations, weak regulatory and institutional regimes governing domestically produced foods could galvanize public opposition to the release of GM products.

Second, the current debate over food quality and food safety, including GM food, often concentrates on the export markets. The tendency is to consider national policies on food safety and standards as necessary to respond to consumer demands in developed country markets rather than the domestic or regional markets. Consequently, decisions over GM food depend on whether a country is targeting the regional market (inter-state trade within Africa) or the foreign market. Given the inconsistent positions being taken by different African countries on importation of GM products, it is unclear if countries would adopt policies aimed at the production of these products for African markets. Consequently, policy positions on GM products would be a major determinant of whether inter-state trade could address the current food deficits in many African.

Biosafety, product standards and trade are inter-related. Recently, debates around biotechnology have heavily tilted towards its implications for international trade, especially agricultural exports. Many African countries are wary of the potential market access barriers in regions sensitive to GMOs, such as the European Union. As already observed, the importation of genetic material used for research is not a contentious issue compared to GM products intended for final consumption as seeds, food or feed, whether processed or not. Within Africa, trade problems arise from the different national regulatory policy regimes; national laws and regulations directly affect the decisions of African countries to commercialise GM products. South Africa provides a clear illustration of this (see box 26 below).

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Box 25: Trade effects of *Bt* cotton and maize adoption in South Africa[161]

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With South Africa producing yellow maize mainly for animal feed and white maize for human consumption, the maize sector been segmented into white and yellow maize markets. Infrastructure and a history of control on what goes where have made it possible to separate GM and non-GM maize, if necessary. South Africa is a net exporter of maize to countries like Japan, Zimbabwe, Zambia, Malawi, Mauritius, Kenya and Mozambique and is capable of supplying non-GM maize, if required. Where non-GM maize is required, farmers have to declare whether they are delivering GM or non-GM maize; the maize is tested and delivered into designated silos. It has also become more common for companies or exporters that require non-GM maize to contract specific farmers to produce maize for them. South Africa has made the decision not to separate GM and non-GM white maize milled for human consumption. However, a couple of companies that produce and export products like maize starches and glucose have, most likely for precautionary reasons, made the decision to only purchase non-GM maize for the time being. Furthermore, South Africa exports a large quantity of yellow maize to cattle feedlots in Namibia and, according to beef export contracts with the European Union, Namibian feedlots must not feed their cattle GM maize.

Although earning a premium on non-GM grain has been more the exception than the rule, demand for non-GM maize exists. The South African maize sector has been able to manage maize grain deliveries well to cater for both maize markets. The situation is different with cotton. South Africa is a net importer of cotton from surrounding countries that only plant non-GM cotton and, with cotton being an industrial crop (non-food), there has been no trade concerns.

The major policy dilemma is whether imported GM products for seeds, food or feed and those developed domestically (through product development and commercialization) require similar policies. Institutions to address these issues remain weak in Africa.

Most African countries have weak regulatory agencies that are lacking either comprehensive legislation or enforcement on food safety and standards. Furthermore, inconsistent positions being taken by different African countries on importation of GM products *make inter-state trade a challenge. African countries must strengthen the role of regulatory agencies to comprehensively address food standards and enforce those standards on issues of trade. National food standards should be harmonized within regional regulatory mechanisms to allow for increased inter-state trade.*

Intellectual property rights

The relationships between intellectual property rights (IPR), international trade and technological innovation have been some of the most controversial issues in global negotiations in recent years. The debate has been largely about the implications of the agreement on the Trade-related Aspects of Intellectual Property Rights (TRIPS) under the World Trade Organization (WTO) for international trade in general, and for developing countries in particular.

The agreement recognizes the role of technology in social and economic welfare and sets out its objectives in Article 7 as: "The protection and enforcement of IPR should contribute to the promotion of technological innovation and to the transfer and dissemination of technology, to the mutual advantage of producers and users of technological knowledge and in a manner conducive to social and economic welfare, and to a balance of rights and obligations." Many of the views expressed by developing countries stem from their perception that the TRIPS agreement affects their ability to use technological knowledge to promote public interest goals such as health, nutrition and environmental conservation.

Currently, U.S. and European private corporations currently hold most of the existing patents on the vectors, promoters, terminators, and even ordinary genes that code certain traits. This is a problem of great implication to African countries, especially WTO members. Most of the arguments for IP exemptions under TRIPS do not apply directly to gene patenting. Until recently, DNA diagnostics based on the polymerase chain reaction (PCR) was problematic because the effectiveness of PCR was based on the heat-resisting properties of the enzyme *Taq* polymerase, which is heavily protected by patents.[162] This constraint was only alleviated recently when the *Taq* polymerase was reclassified as a 'generic' biochemical reagent, substantially reducing the cost of PCR applications in research and commerce. Furthermore, the infrastructure for the protection of the rights of local communities over their knowledge and technologies relevant for biotechnological R&D is either grossly inadequate or lacking all together.

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Box 26: Initiative to address Intellectual Property Issues

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Public Intellectual property Resources for Agriculture (PIPRA), a newly formed a non-profit organisation funded by the Rockefeller Foundation and McKnight Foundation, seek to solve large-scale intellectual property (IP) issues through the collaboration of several universities and foundations. Membership to the organisation is open to any public sector research institution that works on genetically modified crops. The organisation facilitates sharing of technologies and tools among public and private research institutions. The organisation has among its mandates, establishment of a collective public IP asset database and reviewing of public sector patenting and licensing practices. The technologies would also assist in commercializing technologies and make them available for free for humanitarian purposes.

The extent to which these provisions or the absence of IPR regimes in African countries influence their ability to adapt emerging technologies is a question open to scrutiny. This is mainly because biotechnology has emerged in the age of enhanced intellectual property protection in the industrialized countries. Indeed, a variety of institutional innovations to promote access to critical biotechnologies are being developed, including initiatives toward open access technology. One initiative to address the problem of gene patents is the Public Intellectual property Resources for Agriculture (PIPRA) (see box 27).

With the U.S. and Europe private sector holding the majority of biotechnology patents, inadequate policy infrastructure for protecting the rights of local communities, and weak IPR regimes in Africa, debates continue over whether IPR is a tool that grants Africa access to or exclusion from the benefits of biotechnologies. Africa should develop a continental framework for IPR protection, ensuring that local biotechnological innovation is encouraged, global innovation is protected, and local communities are rewarded.

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The provision of appropriate regulatory framework for biotechnology in Africa

Africa is inextricably caught up in the globalisation process. Indeed in Africa's quest to improve cooperation with other regions of the world so as to effectively address trade, R&D and regulatory issues pertaining to modern biotechnology,[163] a major challenge is how to meet and/or adhere to the requirements of the relevant global instruments on the subject as provided for under the relevant institutions such as the World Trade Organization (WTO) and Africa's major trading partners, including the European Union (EU) and the United States (US). Most African States are members of the WTO[164] which has prescribed two Agreements on agricultural and manufactured products: the Sanitary and Phyto Sanitary Standards (SPS) Agreement and the Agreement on Technical Barriers to Trade (TBT).

The SPS Agreement is designed to ensure that countries apply measures to protect human and animal health (sanitary and phyto sanitary measures) based on assessment of risk or for that matter, science. The aim is the establishment of a multilateral framework of guidelines and rules that will orient the development, adoption and enforcement of harmonized sanitary and phytosanitary measures and minimize their negative effects on trade.[165]

Under the SPS Agreement, the Codex Alimentarius is the main instrument for the harmonization of food standards, and constitutes a collection of internationally adopted food standards, codes of practice and maximum residue limits of pesticides and veterinary drugs. WTO members are enjoined to base their national food safety measures on codex standards.

The TBT Agreement seeks to ensure that technical regulations and standards including packaging, marking and labelling requirements do not create unnecessary obstacles to international trade. The TBT Agreement covers all technical standards not catered for by the SPS Agreement, and applies to all food products including agricultural products. Parties can deviate from the TBT's standards to fulfil legitimate objectives such as the prevention of deceptive practices or the protection of human health and safety, animal or plant health or the environment. Such measures can be justified on the basis of scientific and technical information.

In the area of animal health, the Office Internationale des Epizooties (OIE) or World Organisation for Animal Health has been designated under the SPS Agreement as the principal standard setting body. States may apply different standards only where the importing country demonstrates scientifically that national animal health conditions require standards over and above those established by the OIE.

It is these rules prescribed by the WTO which constitute the norms or benchmarks against which the validity, adequacy or otherwise of domestic legislation may be judged.

The status of treaties in any African country will depend on the legal system applicable. In general in the common law jurisdictions, there is a need to have legislation specifically enacted to implement treaties in the municipal systems. However, in other jurisdictions, treaties have automatic binding effect. Whatever be the position in the domestic realm, at international law, a treaty is binding on a state once it has signed and ratified same. Indeed prior to ratification, a state is enjoined not to do anything to defeat the object and purpose of the treaty.

The implementation of these rules in domestic legislation is thus mandatory as they constitute treaty obligations assumed under the WTO; and the implementation of the Codex and TBT standards in national legislation is the appropriate measure of compliance by African countries. These standards should thus be employed as the basis for harmonization in Africa.

The level of implementation of these standards is rather low owing to several constraints. They include: limited technical, human and financial resources. These hamper many of these countries' ability to achieve their health and food safety objectives. Lack of infrastructure, including regulatory and standardizing bodies, accredited laboratories or testing facilities to conduct risk analysis hamper the ability of most states to provide the necessary scientific and technical justification for the sanitary measures they apply to food imports. While most countries have legislative and regulatory frameworks on sanitary and phytosanitary issues, many provisions are outdated and are not harmonized with the SPS and TBT Agreement.[166]

The implementation of the WTO standards has serious implications for trade between African countries and the North. Even though developing countries have won preferential treatment in terms of lower or zero tariffs and other non-tariff barriers for their products, similar concessions cannot be gained over sanitary and phyto-sanitary standards which are regarded as highly sensitive in view of their health implications. Once the standards are in place, the only options are either to meet those standards and export accordingly or drop the idea of exporting altogether. At the end of the day, no consumer would buy anything agricultural that does not conform to prevailing standards. Indeed no such concessions can be gained even under the preferential concessionary arrangements under the ACP/EU Framework.

Since an SPS standard has to be necessary for the protection of human, animal or plant life or health, if the EU accepts lesser standards on goods from ACP countries than it requires of others in similar circumstances, then the necessity of the measure will be in doubt. Therefore a case could be made for arbitrary discrimination since arbitrariness here would have to be interpreted in the context of the prevalence or otherwise of risk in goods coming from any two countries. The most that has been achieved so far at the WTO level in this respect is a promise to assist in the provision of technical infrastructure for compliance with those standards by developing states.[167]

African states should strive to implement the SPS Agreement. In this regard, the limitations faced by African states as noted must be addressed by a programme of capacity building, through international and donor collaboration with organizations such as the WTO, UNEP, FAO, the EU and the US. The FAO, for instance, addresses a variety of food-related activities through publications, training courses and technical assistance projects. The organization collaborates with member countries on strengthening national food control programmes; advice on policy, institutions, regulations, Codex standards; and training and capacity building with regard to laboratories, inspection procedures and good manufacturing and hygiene practices. The FAO Legal Office also has as part of its mandate, the provision of technical assistance to member countries toward the development, formulation and revision of legislative and regulatory framework for food.

With regard to the TBT Agreement, the African Organization for Standardization (ARSO), the competent regional body on standards could draw on the EU experience for the purposes of enhancement and harmonization of Standards in Africa. After a failed experience in setting up of detailed, pan-European technical regulations, the EU decided to establish their technical regulations at two levels: 1) "essential requirements" incorporated in mandatory European Directives issued by the EC for each category of products and 2) more "detailed technical specifications" provided in voluntary standards established through consensus of stakeholders by the European Committee for Standardization (CEN) and the European Commission for Electrical Standardization (CENELEC). These voluntary standards are considered to be one possible way of proving conformity of products to the European Directives.

This approach, known as the "the new approach" has proved to be an efficient means of quickly achieving the harmonization of safety regulations in Europe and it would be logical to recommend a similar approach in Africa where ARSO, based in Nairobi with many years of experience already exist.

Harmonization of standards and technical regulations is, however, not sufficient to ensure safety of products. Effective control of conformity of products to standards and regulations is equally important. The EU has again pioneered an approach to conformity assessment known as the "global approach" since it applies to both regulated and non-regulated products. The objective of this approach is to ensure conformity to standards and facilitate mutual recognition of tests and certificates issued anywhere in the EU.

This approach is based on a set of *conformity assessment modules* suited to different product categories and risks associated with them; combined with a system of mutual recognition of testing and certification activities. Since the currently accepted way of ensuring the validity and equivalence of test results and certificates is through accreditation of the test laboratories and certification bodies issuing them, the system is based on setting up of *accreditation systems* in each country working to the same international standards and connected together through a system of mutual recognition based on international norms in the framework of two international associations: the International Laboratory Accreditation Cooperation (ILAC) and the International Accreditation Forum (IAF).

ARSO could play an important role in facilitating the establishment of a similar system in Africa.

In the field of Biosafety, the major instrument on the subject is the Cartagena Protocol on Biosafety to the Convention on Biological Diversity. 37 countries in Africa have ratified the Protocol. In recognition of the fact that modern biotechnology has great potential for human well being if developed and used with adequate safety measures for the environment and human health, the Cartagena Protocol has as its objectives to contribute to ensuring an adequate level of protection in the field of the safe transfer, handling and use of living modified organisms resulting from modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity, taking into account risks to human health.

To this end, parties are to ensure that the development, handling, transport, use, transfers and release of any living/genetically modified organisms are undertaken in a manner that prevents or reduces the risks to biological diversity, taking into account risks to human health. The central feature of the Cartagena Protocol is its Advance Informed Agreement ("AIA") mechanism, which enjoins exporters to obtain the consent of the country of import before shipping GMOs to the country of export for the first time. A party seeking to export a GMO destined for intentional introduction into the environment must notify the potential recipient country of its intention through the AIA procedure. The potential importing country must then decide whether to permit the importation of the GMO. The Cartagena Protocol mandates the potential importing country to base its decision upon risk assessments carried out in a "scientifically sound manner." Alternatively, the potential importing country may require the exporter to conduct the risk assessment.

The AIA procedure does not, however, apply to LMOs intended for direct use for food, feed, or for processing (LMO-FFPs). In practice, this means, for instance, that while "the export of GM maize seeds for field trials needs to be notified to and approved by the party of import in advance, an exporter who wishes to ship a consignment of GM seeds for use as animal feed in a swine farm would not need to obey the strict notification requirements established by the AIA. Instead, the Cartagena Protocol provides for a different procedure for the regulation of LMO-FFPs, under which a country intending to export LMO-FFPs is merely required to inform the potential recipient country of its decision through the protocol's Biosafety Clearing-House. In effect, the Cartagena Protocol leaves the regulation of LMO-FFPs to the discretion of the importing and exporting parties.[168]

Hence, the Cartagena Protocol which as a norm or benchmark that could guide action on GMOs, does not adequately and/or satisfactorily address the problem of genetically modified (GM) foods; a situation that has compounded the confusion and/or varying stances adopted by African states. Three approaches may be discerned: those states that advocate a total ban on GM foods, those that adopt free and/or liberal importation of GM foods and those that have adopted a restrictive approach to GM food importation.

The approaches have been influenced, inter alia, by the policies of Africa's major trading partners, the EU and the US. The US has taken the approach that GM food products are substantially equivalent to their organic counterparts and should therefore be traded freely, whereas the EU has adopted a precautionary approach to trade in these products on the rationale that they may have adverse impacts on human health and the environment.

These states have utilized bilateral, political and economic pressures to prevail upon African States to adopt favourable regulatory approaches to their cause. These bilateral pressures undermine the policy autonomy of African States to regulate trade in GM food products in the interests of their citizens.[169] Thus even though many African states have or are in the process of implementing biosafety frameworks, there is no uniformity of standards on the subject.

At the AU level, The African Model Law on Safety in Biotechnology (the Model Law) has been adopted as a framework on biosafety regulations for protecting Africa's biodiversity, environment and health from the risks of GMOs. The Model Law was finalized in 2001 and endorsed by the 74th Ordinary Session of the OAU Council of Ministers held in Lusaka, Zambia. The Model Law proceeds on the assumption that measures provided for in the Cartagena Protocol are the minimum, hence African States on the basis of their sovereign rights could adopt more rigorous standards on the subject. Accordingly, the Model Law sets additional biosafety rules that are not dealt with by the Cartagena Protocol.

In Africa's quest to improve cooperation with other regions of the world so as to effectively address trade, R&D and regulatory issues pertaining to modern biotechnology, a major challenge is how to meet and/or adhere to the requirements of the relevant global instruments. It is thus recommended that:(1) African countries should implement the SPS and TBT standards in African domestic legislation through regional and international collaboration; (2) There should be the establishment/strengthening of desks in the RECs supported by experts capable of advising States on the international regulatory framework for Agricultural and manufactured products as provided for under the SPS, TBT Agreements and the Cartagena Protocol; (3) AU/NEPAD should build and retain capacity guide and direct African States on the subject and also act as an advocacy group in dealings with the WTO and other relevant *international institutions and (4) establish regional authorities or agenices under designated RECs to overseas the implementation of harmonized safety regulations.*

Chapter 7: Conclusions

The history of Africa has been marked by a unique development narrative in which science, technology and innovation have often been viewed a preserve for a select few rather than as tools for development in negative terms. But this narrative is starting to change and African leaders are starting to view science, technology and innovation as critical to human development, global competitiveness and ecological management. It is in this context that the findings and subsequent implementation of the recommendations of the High-Level African Panel on Modern Biotechnology of the African Union and the New Economic Partnership for Africa's Development (NEPAD) should be viewed.

The outcome of the work of the panel is the creation of "regional innovation communities" involving groups of countries in eastern, western, northern and southern Africa. The innovation communities may be anchored by "biotechnology innovation hubs" with clusters of capabilities in agricultural, health, industrial and environmental biotechnologies. The hubs or clusters will… The strategies will be implemented through Regional Economic Communities (RECs) whose capacity will in turn need to be strengthened.

To elaborate on this focus, the report: (a) outlines the role of technology in general and modern biotechnology in particular in regional economic integration and trade; (b) outlines priority areas in modern biotechnology of relevance to African development; (c) identifies critical capabilities needed for the development and safe use of modern biotechnology; (d) specifies harmonized regulatory measures needed for advancing research and commercialization, safe use and trade; and (e) proposes strategic options for creating and building regional biotechnology innovation communities and hubs in Africa.

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Africa in the Global Economy

Long-term process of biotechnology development in Africa should go hand-in-hand with the creation of regional economies. Local innovation areas hold the promise of creating competitive, biotechnology-driven African economies that benefit from spatial concentrations of regional innovation actors (universities, firms, and research institutes). There is great potential in developing North-South and South-South collaborations supporting biotechnology R&D and capacity-building in African regional innovation communities and local innovation areas.

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Advances in Biotechnology

There is a natural convergence of S&T policies from various technological disciplines, especially biotechnology, and industrial policies aimed at building manufacturing capacity as a national economic development strategy. Biotechnological tools can be harnessed in Africa for increased agricultural productivity and food security, value-added forestry-related economic sectors, health-care research and services, industrial manufacturing and management, and processes that minimize environmental risks. Biotechnology presents Africa with enormous opportunities and all applications of biotechnology should be adopted that are appropriate to address Africa's needs and economic opportunities. Advances in the life sciences are taking place in conjunction with other technologies. Therefore, those countries that develop capacity in another technological field (i.e. ICTs) are better suited to take advantages of biotechnology.

Recommendation: Countries must seek to develop capacities in all platform technologies whose combined impact will have profound implications for long-term economic transformation. Biotechnology has wider implications for the economic system as a whole. Therefore, policies that seek to advance biotechnology cannot be separate from overall technology and economic policies. Resistance to technology (in another field) has led to negative economic impacts, and similarly resistance to biotechnology will lead to the same consequences.

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Current Status of Biotechnology in Africa

Agricultural biotechnology holds promise for food security, nutrient-enhanced food commodities, and diagnostic kit development for virus detection. Animal biotechnology can help develop vaccines for livestock diseases and infections that threaten food security. Forestry biotechnology can help Africa benefit in areas of tree species biodiversity and reforestation. Human and medical biotechnology can be harnessed to address Africa’s health care systems, with implications for energizing industry-related innovations and, in the long run, improved national and regional economies.

The most promising areas for Africa in the area of industrial biotechnology is in development of bio-fuels, value addition to its raw materials, and conversion of waste into useful products. Industrial biotech can cut the costs of investments while improving the quality of products, provide flexible processing and manufacturing platforms that could easily be modified and adapted. African countries are already harnessing environmental biotechnology to manufacture products aimed at non-chemical environmental management in the tropics as well as to develop and optimise process technologies for removal of biological nitrogen and organic pollutants from the environment.

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Identifying Critical Capabilities

Africa has a wealth of biodiversity that can potentially serve as a resource for wealth creation with the aid of biotechnological tools. Continental challenges require a refocusing and balancing of educational efforts to include the focus on sciences in general and life sciences in particular.

Poor infrastructure and inadequate infrastructure services are among the major factors that hinder efforts to develop Africa and harness the tools of biotechnology to aid in that development.

The ability of African countries and firms to innovate in biotechnology is largely determined by strategic alliances they forge geographically and across sectors. Africa’s meagre R&D investments impair its capacity to stay meaningfully connected to global advances in biotechnology and its ability to transfer, adapt, and exploit life sciences knowledge for the benefit of its citizens.

The current African situation is forcing educational institutions to consider whether their missions connect with the development challenges of the continent Reinventing African educational systems with the focus on S&T is critical for the continents economic recovery.

Africa has very little private sector investment and development, impeding the commercialization capacity required to translate biotechnology research into new products and emerging enterprises. Strict, risk-focused regulatory regimes may hinder the technology transfer, adoption, development, and potential benefits of emerging biotechnologies. Public awareness of and confidence in biotechnology is one of the factors that will influence the extent to which African countries individually and/or collectively adopt the technology. Conversely, lack of awareness and misinformed perceptions of the technology—its nature, benefits and risks—make it difficult for African countries to individually and collectively set priorities and proactively exploit economic and technical opportunities offered by modern biotechnology. Limited availability of funding is one of the major factors that hinder the development of science and technology in general and biotechnology, in particular.

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Strategic Considerations

Africa needs to take strategic measures aimed at promoting the application of modern biotechnology to regional economic integration and trade. Such measures include fostering the emergence of regional innovation systems in which biotechnology-related "local innovation areas" play a key role. But doing so will entail a diversity of complementary measures that include upgrading regional capacities and forging international partnerships. Furthermore, funding such initiatives will involve adopting a wide range of approaches aimed at generating the necessary financial resources, including "innovation funds". Existing funding sources such as international and regional development banks could also play a key role in helping in the commercialization of products from the biotechnology-related local innovation areas.

Regional economic communities should begin to determine potential opportunities for biotechnology specialization and foster regional networking of biotechnology centres for R&D related to this regional specialization. African Regional Innovation Communities should facilitate North-South and South-South collaborations as well as mobilize the knowledge network of its Diaspora for "thickening" emerging Regional Innovation Communities and Local Innovation Areas.

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Governing Biotechnology

Scientific evidence regarding the risks and benefits of GM crops concludes that there is no compelling evidence of harm from the consumption of foods and food products containing GM components. Considerable efforts at policy and administrative developments in the area of transboundary movement and trade in GMOs are taking place in the context of sub-regional political entities. A host of African countries are in the process of developing their biosafety policies and legislation and/or reforming processes to formulate national policies and laws on biotechnology and biosafety.

Most African countries have weak regulatory agencies that are lacking either comprehensive legislation or enforcement on food safety and standards. Furthermore, inconsistent positions being taken by different African countries on importation of GM products make inter-state trade a challenge.

With the U.S. and Europe private sector holding the majority of biotechnology patents, inadequate policy infrastructure for protecting the rights of local communities, and weak IPR regimes in Africa, debates continue over whether IPR is a tool that grants Africa access to or exclusion from the benefits of biotechnologies. In Africa's quest to improve cooperation with other regions of the world so as to effectively address trade, R&D and regulatory issues pertaining to modern biotechnology, a major challenge is how to meet and/or adhere to the requirements of the relevant global instruments.

Annexes

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About the Panel Members

Calestous Juma, Co-chair, Professor of the Practice of International Development at Harvard University's John F. Kennedy School of Government and Director of the Science, Technology and Globalization Project. He is former coordinator of the UN Millennium Project's Task Force on Science, Technology and Innovation whose report, *Innovation: Applying Knowledge in Development*, was presented to UN Secretary-General in January 2005. Juma served as Chancellor of the University of Guyana until 2003 and is a member of the President's National Economic and Social Council of Kenya. Professor Juma is a former Executive Secretary of the United Nations Convention on Biological Diversity and founding director of the African Centre for Technology Studies in Nairobi. He has been elected to various scientific academies including the Royal Society of London, the US National Academy of Sciences and the Academy of Sciences for the Developing World (TWAS).. He has won several international awards for his work on environment and development. He holds a PhD in science and technology policy studies, and has written widely on science, technology and the environment.

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Ismail Serageldin, Co-chair, Director, Library of Alexandria, also chairs the Boards of Directors for each of the BA's affiliated research institutes and museums and is Distinguished Professor at Wageningen University in the Netherlands. He serves as Chair and Member of a number of advisory committees for academic, research, scientific and international institutions and civil society efforts which includes the Institut d'Egypte (Egyptian Academy of Science), TWAS (Third World Academy of Sciences), the Indian National Academy of Agricultural Sciences and the European Academy of Sciences and Arts. He is former Chairman, Consultative Group on International Agricultural Research (CGIAR, 1994-2000), Founder and former Chairman, the Global Water Partnership (GWP, 1996-2000) and the Consultative Group to Assist the Poorest (CGAP), a microfinance program (1995-2000). Serageldin has also served in a number of capacities at the World Bank, including as Vice President for Environmentally and Socially Sustainable Development (1992-1998), and for Special Programs (1998-2000). He has published over 50 books and monographs and over 200 papers on a variety of topics including biotechnology, rural development, sustainability, and the value of science to society. He holds a Bachelor of Science degree in engineering from Cairo University and Masters' degree and a PhD from Harvard University and has received 18 honorary doctorates.

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Amadu T. Ba has a PhD in tropical botany from University of Paris VI and a PhD in natural sciences from University of Senegal. He served as assistant lecturer at the university of Dakar Senegal in 1975 where he rose to the rank of full professor 1989. He has also served as Director of Institute of Environmental Sciences in Senegal since 1982 and Head of Department of Plant Biology from 1984-2004. His main research interest is in ecological and physiological studies on parasitic weeds (*Striga hermonthica* and *S. gesnerioides* on millet), botanical studies of Senegalese flora, in national parks and forest ecology and biodiversity inventory in protected forests. He is a member of National Commission of Man and Biosphere (MAB), the National Commission of UNESCO, National Committee for Natural Resources and Environment (CONSERE), Advisory Board of National Centre of Remote sensing for Ecological Studies and special adviser of Ministry of Education for Biology the Teaching in High Schools. Prof Ba is focal Point and co-ordinator of National Biodiversity Strategy Conservation Elaboration Process, CBD Clearing House Mechanism (CHM) in Senegal and founding member of the national academy of sciences of Senegal. He is president of national committee of Biosecurity in Senegal. His other responsibilities include member of IUCN Commission on Ecosystem Management, Regional councillor for Africa and Vice-President of IUCN, Co-ordinator of African Biosciences Network (ABN) for 10 years as UNESCO Consultant, President of West African Association of Botanists (ABAO), Member of scientific board of AGRHYMET (Niamey) and member of scientific Board for Environment of West African Monetary Union (UEMOA).

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Mpoko Bokanga is a food scientist, with a master's degree from the Massachusetts Institute of Technology (MIT) and a doctorate from Cornell University in the USA, and he has been involved in agricultural research and development in Africa for the past 16 years. Before joining AATF as its first Executive Director, Bokanga worked as Industrial Development Officer (Agro-industries) with the United Nations Industrial Development Organization (UNIDO) in Abuja, Nigeria. He also served as Research Scientist with the International Institute of Tropical Agriculture (IITA, 1989-2002); as a Visiting Professor of Food Science at the Alabama A & M University in Normal, Alabama and as Research Associate with Westreco Inc., a Nestlé Research Company based in New Milford, Connecticut, USA. At Westreco, Bokanga developed processes based on immobilized microbial and enzyme systems, and at IITA, he developed technologies for processing cassava and yams into new products which were deployed in over a dozen African countries. He has co-authored or edited three books and published several papers on the biochemistry and health implications of cyanogenesis in cassava, and on the processing of root and tuber crops; he is the Coordinator of the Working Group on Cassava Safety (WOCAS), a sub-committee of the International Society for Tropical Root Crops (ISTRC) whose main function is to monitor progress in and stimulate research on the understanding and handling of issues related to cyanogenesis in cassava and their implications on cassava food safety. Bokanga is the current chair of ISTRC-AB, the African branch of the ISTRC and he is a Visiting Professor at the University of Greenwich in England (2005-2008).

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Abdallah Daar is Professor of Public Health Sciences and of Surgery at the University of Toronto, where he is also Director of the Program in Applied Ethics and Biotechnology and co-director of the Canadian Program on Genomics and Global health He is also the Director for Policy and Ethics at the McLaughlin Centre for Molecular Medicine, University of Toronto. After medical school in London, England, he went to the University of Oxford where he did postgraduate clinical training in surgery and also in internal medicine, a doctorate in transplant immunology/immunogenetics, and a fellowship in transplantation. He was a clinical lecturer in Oxford for several years before going to the Middle East to help start two medical schools. He took up the foundation Chair of Surgery in Oman in 1988, where he also headed the research labs. He has published four books (on tumour markers; surgical radiology; transplant ethics; and bioscience business ethics) and has over 250 publications in immunology, immunogenetics, transplantation, surgery, and bioethics. He chaired the WHO Consultation on Xenotransplantation and wrote the WHO Draft Guiding Principles on Medical Genetics and Biotechnology. He is currently Chair of the 4th External Review of the UNDP/UNICEF/WORLD BANK/WHO Special Program on Tropical Diseases Research and Training. He is a Fellow of the New York Academy of Sciences and is on the Ethics Committee

of the (International) Transplantation Society and of the Human Genome Organization. He holds the official world record for performing the youngest cadaveric donor kidney transplant. In 1999 he was awarded the Hunterian Professorship of the Royal College of Surgeons of England and in 2005 he was awarded the Anthony Miller Prize for research excellence at University of Toronto. Also in 2005 he was awarded the UNESCO Avicenna Award for Ethics of Science. He has been a Visiting Scholar in Bioethics at Stanford University and Visiting Professor in the Faculty of Law at the University of Toronto. Editorial Boards include World Journal of Surgery, Kidney Forum, Clinical Transplantation Proceedings, J. of Globalization and Health and J. of Genomics, Society and Policy. His current research interests are in the exploration of how science and technology can be used effectively to ameliorate global health and developmental inequities.
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Cheikh Modibo Diarra is chairman of Microsoft Africa He was born in Nioro du Sahel (Mali). He holds a Bachelor of Science in mathematics and analytical mechanics of the University of Jussieu in Paris , has taught spatial mechanics at the Howard University in Washington. He then joined the NASA as an astrophysicist and was in charge of important spatial exploration programs. Ambassador to UNESCO, he chairs the African Group for Basic Space Science, an organization whose aim is to promote the development of high-tech sciences in Africa and to set up a university for advanced technologies on the continent. He also initiated the African annual summits for the promotion of science and technology among the younger generations, in collaboration with the University of Nouakchott (Mauritania) and the Pathfinder for Education association, of which he is the scientific committee president.
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Tewolde Berhan Gebre Egziabher is the Director General of the Environmental Protection Authority of Ethiopia. He is the spokesperson of the African Group in the Cartagena Protocol on Biosafety and a member of the Compliance Committee of that Protocol. He is also a member of the Interim Panel of Eminent Experts to establish the Global Crop Diversity Trust under the FAO, a member of the Panel of Eminent Experts on Ethics in Food and Agriculture of the FAO and the Chair of the African Group in the Contact Group to develop the Standard Material Transfer Agreement of the International Treaty on Plant Genetic Resources for Food and Agriculture. In 1995, together with his wife, he started the Institute for Sustainable Development, which worked on a project with some farming communities to reverse land degradation, revegetate the land and raise agricultural production. The success of that project was such that it is now adopted as a country-wide programme.

Dr. Tewolde developed the Conservation Strategy of Ethiopia, which has become the basis for environmental protection in Ethiopia. While he was doing this, he represented Ethiopia in negotiating Agenda 21, the Convention on Biological Diversity and the Convention to Combat Desertification. He was the chief negotiator of the African Group in the International Treaty on Plant Genetic Resources for Food and Agriculture. He was also the chief negotiator of the developing countries in the Cartagena Protocol on Biosafety.

Dr. Tewolde is a plant ecologist with a Ph.D. from the University of Wales. His academic career has included university teaching, research and academic administration. He was Editor of *SINET: an Ethiopian Journal of Science*, Leader of the Ethiopian Flora Project and Dean of the Faculty of Science in Addis Ababa University, and President of the Asmara University. He has many publications and is a member of the Biological Society of Ethiopia and the British Ecological Society, among others. He has won several awards, including the Right Livelihood

Award of 2000 and an honorary degree of Doctor of Science from Addis Ababa University in 2004.
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Lydia Makhubu obtained a PhD in Medicinal Chemistry at the University of Toronto in Canada and then joined the University of Swaziland as lecturer in Chemistry. She rose through the ranks to become the Dean of Science and later she was appointed Vice Chancellor of the University. She has served in many organizations concerned with higher education, science and technology, the education of women in Africa. She is currently the Chancellor of the only Women's University in Southern Africa.

For many years she was the President of the Third World Organization for Women in Science. Through out her academic life Prof. Makhubu has been actively involved in research on medicinal plants and has served on several national and international committees on traditional medicine. She has been awarded honorary degrees by the University of Wales (1991), Queen's University, Canada (1991), St Mary's University (1991), Council for National Academic Award for London (1992), Brandon University (1995). She is currently an Honourable Senator in 8th Parliament of Swaziland.
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Dawn M.M. Mokhobo has a Bachelors degree in Sociology. She is one of South Africa's leading managers and businesswomen, with a highly successful and pioneering career spanning the public, private and parastatal sectors. Her talents and accomplishments were recognised in particular by her appointment as the first Black woman to the Management Board of Eskom, as Executive Director in charge of Growth and Development. In this position Dawn played a pivotal role in aligning the organisation with the demands of the changing national and international environments and positioning Eskom to be one of the role models amongst South African organisations. Prior to this Dawn worked as Senior Manager and Senior General Manager (Human Resources) for Eskom and as Senior Divisional Health Education Manager for the Anglo-American Corporation. She has also served as Group Manager in charge of Community Development for the then Bophuthatswana Agricultural Development Corporation, as a Medical Social Work Manager in Bophuthatswana, and as a Social Worker in the Orange Free State. For two years she successfully ran her own Public Relations and Development Consultancy.
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Lewis Mughogho obtained a PhD in Plant Pathology from University of Cambridge. He has served in several positions as research fellow in agricultural botany at the University College of Rhodesia and Nyasaland, Plant pathologist at the Agricultural Research Council of Malawi, founder head of the crop production department at the University of Malawi and Principal of Bunda College of Agriculture University of Malawi where he was promoted to the rank of Professor. Prof. Mughogho joined the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) as Principal Plant Pathologist and sub-programme leader in 1979 where he rose to the position of Executive Director of the Southern and Eastern Africa Regional Programme . He is currently Acting Director of the Tea Research Foundation of Central Africa.
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Samuel Nzietchueng obtained a doctorate degree in crop production/pathology from the University of Cameroon. His is currently working as Director of Research in the Cabinet of the Secretary General of the Ministry of Scientific Research and Innovation in Cameroon. He served as Director General of the African Agency of Biotechnology during the period 1995-2005. Dr.

Nzietchueng is an agronomist, physio-pathologist and international development specialist with thirty-two years of experience working in Europe, USA, the Caribbean and Africa (all sub regions). His has served in portfolios involved in managing international intergovernmental organization and designing multi-sectoral and multinational programmes in the areas of agriculture production and biotechnology. He has extensive experience in creating effective relationships with international and national research institutions. He has been actively involved in teaching and supervising research works for masters and doctorate students.

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***George Agyemang Sarpong* joined** the Law Faculty, University of Ghana in 1990 having retired honourably from the Ghana Armed Forces, in the rank of Major. George is a product of the Ghana Military Academy, the Combat Arms School, Canada, the Faculty of Law University of Ghana, the Ghana School of Law and the University of British Columbia, Canada.

Since 1990, he has taught and researched in Public International and Environmental Laws, the latter at graduate and undergraduate levels. He has published extensively in local and international journals and books on Public International and Environmental Laws and contributed substantially to the development of Ghanaian Environmental Law and Policy. Professor Sarpong has also been a recipient of several Fellowships and Visiting Scholarships including: the UN and Leiden, Nottingham, Queens (Belfast) and North-western Universities. Outside academia, he has been involved in several activities as legal consultant to the Government of Ghana, UN bodies and other international organizations in the implementation of projects, programmes and policies in Environmental Law and Policy in several sectors including Irrigation, Wetlands, Water Privatisation, Land Use Planning, Biodiversity, Mining, Environmental Health, Food Safety and Plant Health. He has served and continues to serve on several Boards and Committees in and outside the University. He is also a member of several national and international organizations, including: the Ghana Bar, the Ghana Legal aid Board, Network of Environmental Lawyers in Africa, African Society of International & Comparative law and the IUCN Commission on Environmental Law.

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Cyrie Sendashonga is trained as a biologist, holder of a PhD from the Free University of Brussels (Belgium), with specialization in molecular biology and cellular immunology. She is a Fellow of the World Academy of Art and Science. Since July 1999, she holds the position of Senior Programme Officer at the Secretariat of the Convention on Biological Diversity (CBD) of the United Nations Environment Programme (UNEP) based in Montreal, Canada, where she is the Head of the Biosafety Programme. In this capacity, she is responsible for guiding, leading and coordinating the activities carried out by the CBD Secretariat in support of the implementation of the Cartagena Protocol on Biosafety.

Before joining the CBD Secretariat, Cyrie Sendashonga spent six years (1992-1998) at the UNEP Headquarters in Nairobi, Kenya, where she was involved in the programme activities dealing with biodiversity and biotechnology issues. Among other activities, her focus centred initially (1992-1995) on the UNEP sub-programme on microbial resources and related biotechnologies that could be utilized for sound environmental management. Before joining the United Nations, Cyrie Sendashonga spent her post-graduation years (1979-1986) working at the International Laboratory for Research on Animal Diseases (ILRAD, which later became ILRI, based in Nairobi, Kenya), one of the Centres belonging to the Consultative Group on International Agricultural Research (CGIAR), conducting research which was focusing on developing new approaches to control parasitic infections in livestock animals.

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Ahmed M. Shembesh is a Libyan national. He has a PhD from University of Liverpool, UK. He joined the University of Garyounes where he rose to the rank of full Professor and also served as chairman of the Department of Urban Planning at the Faculty of Engineering. Prof. Shembesh was appointed in 1987 by the Libyan Government to establish the Libyan National Centre for Standardisation and Metrology. In 1996 he was appointed by the Libyan Government as the Technical Manager of the Universal Inspectorate and Services (the main governmental inspection company), which inspects all major commodities imported to Libya. During 2003 – 2004 he worked as a consultant to the Secretariat of Planning as well as to the Libyan Railway Authority. In 2004 he was re-appointed Director General of the Libyan National Centre for Standardisation and Metrology. Prof. Shembesh is also the chairman of the National Committee for the Evaluation of the Regional and Urban Master Plans in Libya. He is also chairman of National Codex Alimentarious Committee. He is a certified auditor for quality management systems.

High-Level African Panel on Modern Biotechnology Terms of Reference

The development and application of modern biotechnology has opened up a wide range of possibilities, including the production of genetically modified crops, animals and micro-organisms. These developments are, however, characterized by increasing scientific complexity, policy uncertainty, and public anxiety over real and perceived benefits and risks. These issues impinge on intra-regional and international cooperation.

No where is the need for regional cooperation likely to be more pronounced as in Africa. This is mainly because most of the African countries do not have the necessary policies, infrastructure, capacities and other resources to individually or collectively regulate and manage the development and application of genetic modification and biotechnology generally. Moreover, increasing intra-regional and international trade (and food aid) in products of genetic modification are exposing the benefits of regional approaches to managing the technology in Africa.

African governments have recognized the importance of regional cooperation to address possibilities and the range of issues associated with biotechnology and genetic modification. Within the framework of the New Partnership for Africa's Development (NEPAD) they have resolved to promote programmes that will "generate a critical mass of technological expertise in targeted areas that offer high growth potential" from biotechnology and the second is to "harness biotechnology in order to develop Africa's rich biodiversity and … improving agricultural productivity and developing pharmaceutical products."[170] To realize these goals African countries will need to first and foremost build common consensus and strategies on how best to ensure that they maximize benefits from the technology while at the same time addressing potential environmental, health, ethical and economic risks or concerns emerging with rapid advances of the technology.

The first NEPAD ministerial conference on science and technology "resolved to build regional consensus and strategies to address concerns emerging with advances in new technologies, including biotechnology, …" The conference called upon the Secretariat of NEPAD to: "build a broad consensus on issues of common concern and develop effective strategies including joint R&D programmes where appropriate; and establish ways and means to build Africa's capacity for risk assessment and management of bio-safety, in particular promote the establishment of regional and sub-regional bio-safety facilities; and facilitate Africa's participation in international fora, processes and discussions on global biotechnology issues."
In the context of the African Union (AU), African leaders resolved to take a common approach to address issues pertaining to modern biotechnology and biosafety by endorsing decision EX.CL/Dec. 26 (III) that calls for an African common position on biotechnology.

The second meeting of the NEPAD Science and Technology Steering Committee decided that the NEPAD Secretariat and the AU Commission establish a high-level panel of eminent persons/experts to advice Africa on the scientific, policy and legal issues pertaining to the development, commercialization and application of modern biotechnology.

It is in response to the above resolutions and decisions that the Secretariat of NEPAD and the AU Commission are establishing a High-Level African Panel on Biotechnology (APB). It will be a body of eminent experts to advise the AU, its Member States and its various organs, on current and emerging issues associated with the development and application of modern biotechnology. Its specific remit is to provide the AU and NEPAD with independent and strategic advice on developments in modern biotechnology and its implications for agriculture, health and the environment. It will focus on intra-regional and international issues of regulating the development and application of genetic modification and its products. The APB will specifically consider:

(a) The current and potential developments in modern biotechnology outlining the implications that may be associated with adoption and/or non-adoption of such technologies for regional economic and trade integration;
(b) The specific priority areas that offer high potential for regional R&D, including aspects of risk assessment and management;
(c) Whether and what aspects of the development and regulation of modern biotechnology should be harmonized into a regional/continental regulatory regime for shared R&D and technology management (this may include ways and means of integrating regulatory measures in existing Regional Economic Communities (RECs) and related trade arrangements);
(d) The scientific capacity that will be needed to ensure the safe application and use of products derived from modern biotechnology, including human resources for research, laboratory testing, safety evaluation and enforcement;
(e) Strategic ways of building Africa's scientific capacity for regionally oriented regulation and management of modern biotechnology; and
(f) Ways of improving cooperation with other regions (particularly Asia and Latin America) of the world to effectively address trade, R&D and regulatory issues pertaining to modern biotechnology, including implementation of the Cartagena Protocol on Biosafety and the Codex Principles on risk analysis of food derived from modern biotechnology;

The panel shall make recommendations on the nature of regional institutional arrangements that are required to promote and sustain common regulatory approaches to the application and use of, and propose a strategy and policy on modern biotechnology. Tenure for the Panel is 18 months commencing at the first meeting. This meeting will be held in Johannesburg, South Africa.

The APB's work shall be serviced by the AU Commission and NEPAD Secretariat. During its first meeting the Panel shall make decisions on the nature of literature and background papers that it will require. AU/NEPAD will seek to commission component research institutions or persons to prepare the papers on the basis of terms of reference prepared by the panel. All the documentation required by or available to the APB will be posted on www.nepadst.org unless decided otherwise by the panel.

An individual African country or government may seek advice of the Panel on a particular issue if such an issue has specific implications for regional cooperation. The Panel must at its first meeting interpret its mandate and the Terms of Reference. It ought to delineate clearly the range of scientific and non-scientific issues that fall within its mandate, those that fall clearly outside it, and those related issues that need to be addressed by other bodies to provide comprehensive answers to the questions posed by the mandate.

The Panel shall submit its report(s) to President Konare, Chairperson of the AU Commission, for transmission to the AU Summit through its subsidiary bodies.

Modus operandi of the Panel

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Independence

The panel will operate without influence from outside and will do so by upholding the highest of professional standards. It will operate in a frank and open manner.

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Confidentiality

The contents of the discussions will not be disclosed outside the Panel but the final report will be made public without attribution to individual members.

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Conflict of interest

Disclosure of potential conflict in regard to financial interest, prior positions as well as family or other relationships

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Transparency

Include here the fact that the various drafts of the Panel will be made available to the public for input and comment.

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Submissions and consultations

Indicate here the ways by which the Panel will receive submissions. Also indicate the kinds of consultations the Panel will undertake, including those provided for in the TORs.

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Role of the secretariat

Organization, writing, etc on the basis of input from the Panel.

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Relationship with sponsoring institutions

Indicate here each meeting will start with a session to brief the sponsoring institutions which will in turn provide feedback. The rest of the proceedings of the Panel will be conducted by Panel members only and the secretariat will be on call to contribute as requested by the Panel.

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Open sessions

Sessions of Panel involving outside presenters shall be open to members of the public on the basis of availability of space. Agendas of future meetings will be made available to the public through the web and to member states through their missions to the AU.

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Press relations

The co-chairs will speak to the press and in keeping with the spirit of the status of work.

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Consensus and dissent

The Panel will make every effort to arrive at a consensus position but in the event that there are issues that are central to the overall terms of reference for which consensus cannot be reached, dissent will be record. This route, however, will be pursued in extraordinary circumstances. Every effort will therefore be made to arrive at common position. Where such differences are a result of divergent approaches to solving specific problems, the report will provide the competing positions are options. Given the diversity of conditions in Africa, efforts will be made to provide action items are options that actors can choose from.

Work Plan

August 2005	First Meeting of the Panel
September 2005	Completion of outline
	Completion of concept paper
	Open call for input
January 2006	First draft paper
	Second meeting of the Panel
April 2006	Second draft
	Third meeting of the Panel
July 2006	Interim report
	Fourth meeting of the Panel
October 2006	Final Report
	Fifth and last meeting of the panel

Endnotes

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