centrate in various components of the aquatic ecosystem (in mud, on plants, and in aquatic animal life).

5) Monitoring a combination of streamwater, mud, and aquatic life is inadequate because of the persistence of these compounds, which makes it difficult to relate the presence of the insecticides to the time and place of their introduction.

A suggested partial solution of these problems would be the establishment of minimum permissible concentrations in point-source discharges containing such materials. This would be an attainable objective that would result in reduction of the concentrations of such persistent materials.

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East Africa: Science for Development

The impact of science in a developing region reveals long-term personnel and research requirements.

Thomas R. Odhiambo

There is agreement among political leaders, administrators, and scientists that accelerated science development in Africa can best be effected by the systematic application of the great corpus of scientific knowledge to problems in the social and economic fields. Numerous international conferences have been convened since the beginning of the decade to discuss science as a modernizing tool in the newer countries. Three of these stand out: the International Conference on Science in the Advancement of New States, held in August 1960 at the Weizmann Institute of Science, Rehovoth, Israel; the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas, held in February 1963 in Geneva; and the International Conference on the Organization of Research and Training in Africa in Relation to the Study, Conservation and Utilization of Natural Resources held in July 1964 in Lagos, Nigeria. In general, one may conclude from the resolutions approved at these conferences that great emphasis is laid on the application of existing scientific knowledge to the solution of pressing economic and social problems of the developing countries. Indeed, science is thought of very much in terms of a *tool*.

This concept of science as a modernizing tool immediately raises a number of important issues. What is the cultural framework of these societies? Have they an educational program to match the heavy high-level manpower requirements that a modern industrial country demands? What type of science policy and science administration should these countries adopt? Is it valid to believe that only the technological results of science are important to developing countries? What should be our priorities in research? In considering these questions, I cannot claim to speak for the whole of Africa, let alone all "the newer developing countries." The only developing region that I know passably well is East Africa. My attitude and remarks will therefore be heavily colored by my experience in East Africa.

Administration of Science

The administrative structure for science in East Africa and in the newly independent African countries is largely a legacy of the colonial interlude. No important structural changes have as yet been implemented to give it a new look

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or to assign to it new functions (*1*). East Africa is an example wherein scientific research is administered through three main channels: within the University of East Africa (*2*); by the various specialized departments of the governments of Tanzania, Uganda, and Kenya; and on a regional basis by the East African Common Services Organization (EACSO). The manner in which the three channels contribute to the total research effort has been set out clearly by Uganda, and may serve as a general model for the whole of the region (*1*). The Uganda government believes that the University of East Africa should concentrate its research resources on "free fundamental research," the EACSO on "oriented fundamental research" and "applied research," while the national government departments should emphasize applied research and development work (*3*).

The administration of science in the University of East Africa is not the direct result of a colonial tradition, since the University was established at about the time that the three East African states were attaining independence (*4*). The University has largely been regarded as a teaching institution and source of high-level manpower for various fields of government and private enterprise (*5*). Only an infinitesimal number of East African graduates stay on to pursue postgraduate work, and a negligible proportion of the institutional budget is set aside for research expenditure (*6*). However, the University authorities are aware that the University, like the older universities, must serve at least three functions: that of acting as a repository of accumulated human knowledge, of teaching, and of circumscribing the perimeter of our ignorance (*5*, *7*).

The pattern in the specialized departments of the national governments is quite different. Routine investigations (such as soil analysis for road building, forensic analysis for criminal investigation, identification of insects for pest control, and river-flow analysis for irrigation works) and the task of undertaking short-term investigations of practical problems (such as the testing of local materials for the building industry, malaria eradication measures, survey and diagnosis of tuberculosis, and mineral exploration) are performed by research establishments scattered throughout a large number of government departments: agriculture, forestry, game and fisheries, health, animal husbandry, public works, tsetse control, and others. In colonial times, the governor of the territory would generally have a legislative or executive council to advise him on the whole range of government business. Science administration was not included among these. The coming of independence has not changed the situation. Each government ministry is still in full charge of its research programs. There is no one ministry or national science policy committee to coordinate the research programs on a national basis (*8*, *9*). The only control of the specialized departments in connection with their research programs is that exercised through the treasury and through the ministries of planning and economic development, which are now a feature of the East African national governments.

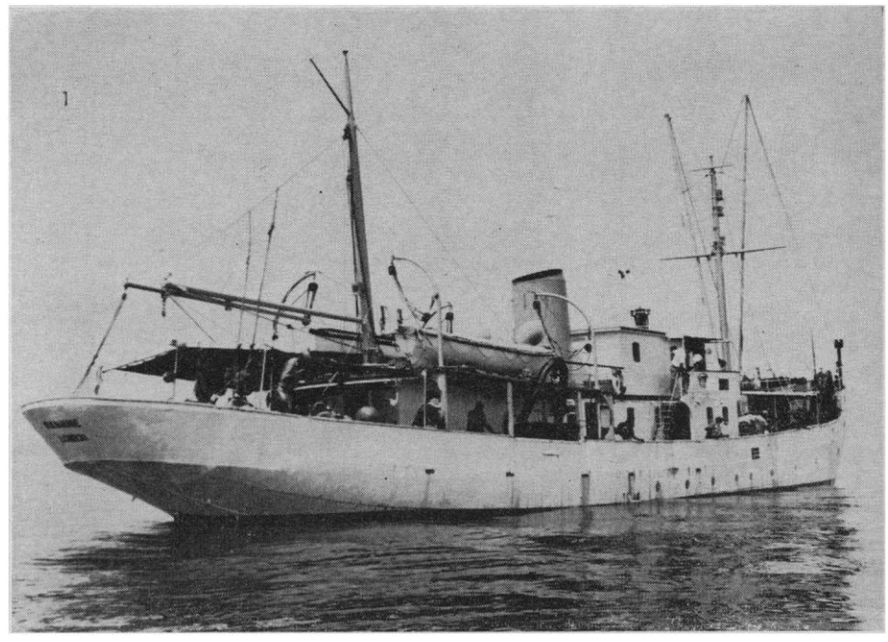

Fig. 1. The research ship *Manihine* is used by the East African Marine Fisheries Research Organization for its oceanographic and fisheries (including plankton) surveys in the Indian Ocean.

One reason for this lack of coordination at the national level is that the colonial government customarily obtained a great deal of advice from British-based research establishments (*8*), such as the Directorate of Overseas Surveys, the Tropical Products Institute, the Anti-Locust Research Centre, and many others. Another reason for lack of coordination is that the colonial governments could call upon British-based advisory bodies for the determination of science policy (*8*), such as the Overseas Research Council, established in 1959 by the British government to coordinate advice and assistance on scientific research. In the absence of any clear governmental statement whether the links with the British-based research establishments will continue, albeit modified to conform with present conditions, the only clear conclusion one can reach is that national science policies are less coherent than they were even in their disorganized state during the colonial period (*8*, *9*).

Administration of research at the regional level is undertaken by the EACSO (*10*). Under it, three East African states share a number of joint ventures—the East African Airways, the East African Railways and Harbours, the East African Postal Services and Telecommunications, and the Common Fund Services (customs, income tax, and research institutes) (Fig. 1).

The shortcomings of the current scheme of regional science administration have been recently described in detail. However, I should like to emphasize that the EACSO has put to the test a plan for coordinating research policy and programs and that it can account for its £2 million budget on scientific research in terms of both oriented fundamental research and applied research—something that the national governments have still to do.

It may be instructive if I briefly summarize the main weaknesses of science administration in East Africa:

1) There is no one body within the

Table 1. Appropriations for the regional East African research establishments (*8*, *11*). The figures in the last two columns are estimates.

Type of research	Appropriations (thousands of pounds sterling)*						
	1960	1961	1962	1963	1964	1965	1966
Natural resources	474	470	442	576	562	639	858
Medical	176	185	302	311	294	328	371
Industrial	43	49	50	49	53	60	68
Total	693	705	794	937	910	1,025	1,297

* One pound sterling equals $2.78.

national governments which coordinates research programs, works out science policy, or determines research priorities.

2) The research effort is channeled along very traditional lines. Almost all programs are in the agricultural or medical fields, little in the industrial field (Table 1). In the fields of meteorology and atmospheric sciences, which are important to a tropical region (Fig. 2), there is no research council nor does the budget allow extensive research.

3) There is no one authority within the EACSO which coordinates research in all fields, thereby fashioning a coherent science policy which notes the gaps in the regional research effort.

4) Of the 100 to 120 senior research workers in the regional research establishments only about 25 percent are East African scientists who hold substantive posts or are in training. Coupled with this problem is the present British/EACSO arrangement by which the British government finances regional research services with matching grants (*11*). A large proportion (one-third of the total) of the British grants go toward expatriation allowances, gratuities, traveling, and other expenses for the British scientists working in East Africa, who form the majority of research workers in the EACSO research agencies. There is no agreement that this granting system will continue after 1969, nor is the current agreement concerned with the financing of new research establishments.

This brings me to the twin problems of the supply of East African scientists and of the financing of research.

Brainpower Resources

Of all the several international conferences on the application of science to development referred to previously, the Lagos Conference particularly caused the African countries to become acutely aware of the shortage of the high-level manpower required for their ambitious development plans. This shortage is most dramatic in those science-based sectors of the economy or services which might lead to social development.

A comprehensive inventory of the research personnel and establishments in 41 countries in Africa was made for the Lagos Conference and has now been brought up to date. It is clear from Table 2 that the available research manpower potential is woefully small. There are about 3000 trained research workers in Africa now. Even discounting the fact that a large proportion of this number are non-Africans, the number constitutes only 6 percent of the actual requirements. The Lagos Conference adopted a conservative target for Africa of training and employing 200 scientists (including university teachers) per million inhabitants (*12*). This implies that Africa needs now about 49,000 scientists and about 70,000 by 1980 (*13*).

The overall shortage of scientists is not as desperate in East Africa as it is in other African countries. In the current 5-year development plan for Tanzania, for example, the latter should aim at having 2400 scientists, if the country adopts the Lagos Conference target. However, the government has estimated that the science-based occupations would need 1437 scientists (excluding graduate teachers) during 1964–69 plan years; the estimated supply would be 843, thus leaving a shortage of 594 scientists (*14*). Consequently, the estimated supply until the next decade is only about 35 percent of the requirements. When one places these figures beside the estimated Tanzanian science student population within university institutions in East Africa, a sense of despondency prevails (Table 3).

It is, therefore, understandable that African governments (including East African ones) should take vigorous national and international steps to rectify this lamentable position (*12*, *15*). Only a few of these can be mentioned here.

Table 2. Inventory of scientific research personnel and establishments in 41 independent countries in Africa. The data are modified from those of reference *1*.*

Science	High-level research workers	Research institutions
Mathematics and physical	163	39
Biological	226	87
Earth and space	566	102
Medical	400	72
Agricultural and food	1406	355
Fuel and power	2	1
Industrial research	71	13
Total	2834	669

* This inventory does not include research personnel and establishments in South Africa, Mozambique, and Angola.

New Science Teaching Ventures

The most ambitious effort in this area is the UNESCO-sponsored Pilot Project on New Approaches and Techniques in Biology Teaching in Africa—a program of fellowships to enable graduate biology teachers to study modern trends in biology teaching in the more advanced countries, and to produce prototype teaching materials in biology for adoption in the various African countries. One hopes very much that the result will be teaching materials of the standard of the Physical Science Study Committee's high school physics course or the Biological Sciences Curriculum Study textbook and teaching aids.

An equally ambitious program for the teaching of mathematics has been launched by a private group—the African Education Program of the Education Development Centre (formerly Educational Services Incorporated), with funds provided by the Ford Foundation, the Louis and Pauline Cowan Foundation, Inc., and other private donors, and the United States government (through the State Department, the International Cooperation Administration, and the Agency for International Development) (*16*).

At least two government centers have been established recently to develop new curricula in science teaching in schools, one at Nsukka, eastern Nigeria, and the other at Nairobi, in Kenya. The Nairobi Science Teaching Centre, which is the more advanced of the two, is a constituent part of the Curriculum Development and Research Centre, ad-

ministered by the Ministry of Education and generously supported by funds and personnel from the Ford Foundation and the Education Development Center. The Science Teaching Centre is conducting a number of experiments in teaching science in primary schools, and it has also produced a number of experimental teaching materials for secondary schools (*17*).

An imaginative scheme to relieve the shortage of science and mathematics teachers has been inaugurated by Tanzania in association with the University College, Dar-es-Salaam (*18*). The government is recruiting university students for training in science education by awarding grants to those intending to study science and mathematics with the condition that they will go into teaching for at least 5 years after completion of their university training. The University College has adopted a novel system of teacher training, in which education and two science subjects are concurrently studied for credits toward the attainment of a B.Sc. degree at the end of 3 years. The course is interspersed with teaching practice in schools.

Although Kenya has now adopted a modified scheme of this sort in association with the University College, Nairobi, the government has inaugurated another project that promises to produce a large number of science school teachers. This is the Kenya Science Teachers' College, which is being established with massive financial aid (£2 million) from the Swedish government —given as an independence gift to Kenya.

It is true that the scarcity of scientists in East Africa (and probably elsewhere in Africa) has been due to poor teaching and to the lack of job opportunities in the past. But is it not possible that there may be something in the cultural attitude and social philosophy that may discourage a tradition in science?

Table 3. Projected entries of Tanzanian science students into university institutions in East Africa (data from conference *14*).

Expected entries	Numbers					
	1964*	1965	1966	1967	1968	1969
Form 6	260	400	440	480	520	640
University of East Africa	125	181	218	251	273	336
Technical colleges	11				8	10

* These represent actual figures.

African View of Nature

It is my view that the African's monistic (one-world) view of nature has proved an impediment to his becoming a natural scientist (*19–22*).

The most important philosophical concept of the Nilotes' culture (*23*) is the concept of *Jok*. *Jok* can mean three things at the same time: (i) it can mean "the greatest spirit," the great "mover of all things," the creator and sustainer of the world and everything in it, or the equivalent of the Christian idea of God; (ii) it can also mean the spirit, or ghost, or witchcraft, or some form of spiritual power; and (iii) it can also mean the body or matter. One cannot dismiss this concept as merely superstition or a form of animism. The *Jok* concept permeates the Nilotic idea of the universe, of existence, and of destiny; for *Jok* is present in all things, living and nonliving, to a greater or lesser extent. Thus *Jok* is held to be the first or sustaining principle or the ultimate explanation for everything. In other words, it is, to the Nilotes, the logical first principle equivalent in its setting and role to the Aristotelian metaphysical idea of "the first mover" (*22*).

Jok is a kind of life-force or vital power or just power (*24*). Being is force, and the latter is not a mere attribute of being which can be measured in physical units as in Western philosophy. Consequently, one may consider that every being is force—plants, animals, inanimate objects, God, spirits, and men. The force does not, as it were, permeate the universe uniformly, but it is contained in individual beings according to a hierarchical arrangement—with "the greatest spirit" (or God) himself possessing the most life-force, and inanimate objects, the least. These individual forces continually interact and influence one another.

A similar philosophical system is held by the Bantu (*24*, *25*), who form the preponderant part of the population of Africa south of the Sahara.

Father Tempels (*24*) makes two observations which are relevant to the thesis stated at the beginning of this section. First, the basic difference be-

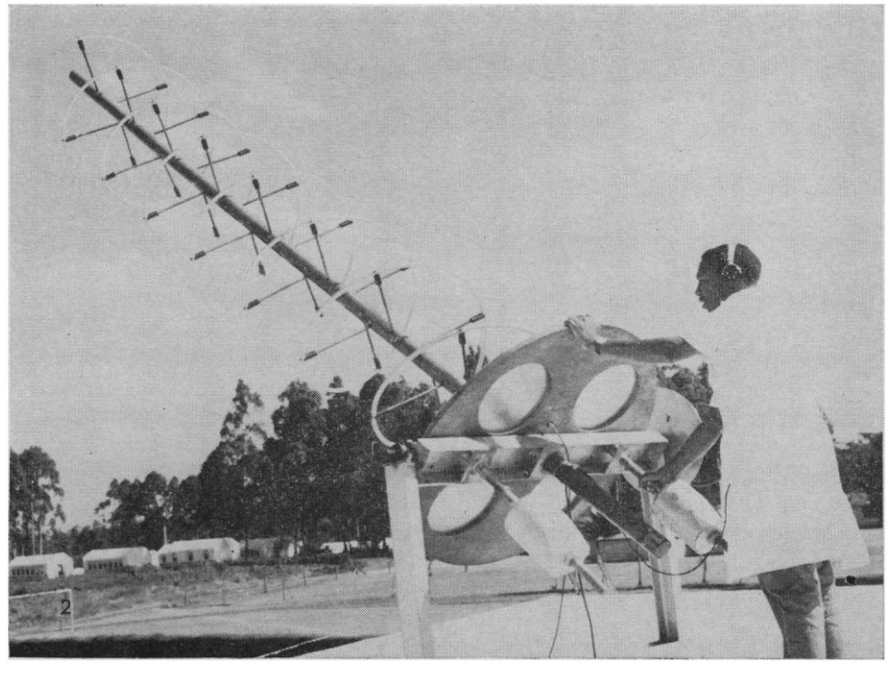

Fig. 2. The East African Meteorological Department now receives daily pictures of the cloud distribution over a large part of Africa direct from the ESSA-2 weather satellite launched by the United States in 1966. Here a technician of the department is moving a helical aerial into position at the receiving station at Dagoretti Corner, Nairobi, Kenya.

tween African philosophy and Western philosophy is that the former is based on a concept of being that is dynamic (being is "the force which is"), whereas the latter is static (being is "that which is"). Second, African philosophy is a monism (a one-world view), while Western (and Indian) philosophy is a dualism (a subjective as well as an objective world).

These observations have important consequences for the African's participation in science. In this African philosophy there is no sharp distinction between the subjective and objective worlds, as we find in European and Indian philosophies. In the case of the European, his attempts to make these distinctions have resulted in science; that is, scientists have had to distinguish between belief, faith, taste, and so forth (the subjective world), and the objective impersonal world. In the case of the Indian, his attempts have led him to treat the world as mere appearance (*maya*); the world exists only in the mind; therefore, there is no objective universe or absolute reality awaiting discovery. Thus, the Indian has mysticism rather than science. As for the African, his monism has deprived him of the choice between either science or mysticism; instead, he has concentrated his intellectual powers in devising a vastly intricate social and communalistic system (*26*).

We can now understand why science, in the modern sense, has no firm foundations in African society. It is, therefore, pertinent to ask again one of the original questions I posed at the beginning of this article: Is it valid to believe that only the technological results of science are important to developing countries? Surely, for Africa, it is more than that. Africans do learn scientific techniques very rapidly—witness the number of first-class surgeons that have been produced, when opportunity is available, in Africa. But if we wish the African to embrace more science than merely technology then we must reach the basic root of the problem, his monistic world-view, and modify it in a manner in which he can begin to regard Nature apart from himself or other beings (*20, 21*).

Fashioning a New Science Policy

The need for more public understanding of science has been stated many times in recent years. But in Africa it is a first-priority requirement for future development—not only in the economic field but also in modernizing its social fabric. This suggests that a radically new approach to science teaching is needed, beginning with the first year of primary school. It means that the rewriting or remodeling of teaching materials which have been successful in the West or in the East is not enough. We will have to begin from the beginning, with the help of African social scientists and philosophers. This should be the foundation of any new science policy for Africa.

Table 4. The (percentage) composition of domestic output as indicated by Green's data (*30*).

Division	Products (%)		
	Ghana	Tanzania	Kenya
Agriculture	47.9	47.8	41.4
Direct-labor investment	2.3		
Mining	4.8	2.2	0.3
Industry	27.5	19.4	24.1
Tertiary	17.5	30.6	34.3

The development of an effective advisory agency in the scientific field is another high-priority need for Africa. At the moment only a few countries have either academies of science (for example Ghana and East Africa) or national research councils or their equivalents (such as the United Arab Republic, the two Congos, Cameroon, and Senegal). The Lagos Conference recommended the establishment of such bodies (*12, 15*); and this has been further strengthened by the 14th session of the UNESCO General Conference held in October 1966 in Paris which requested the Director-General to initiate or stimulate action in this direction (*27*). It will require considerable thought to determine whether, in the case of academies of science, a country should adopt the Ghanan model (with a strong executive body that controls funds, administers all research institutes, and advises the government on science policy), or the East African model (a loose, privately run academy with no formal links with the government).

A similar decision must be made with respect to the structure and proper role of a national research council. Should one choose a purely advisory body, such as the government of the three East African states are now considering? Or should one seek government apparatus, such as a ministry of science (*28*)?

Experience in East Africa leads one to believe that science policy needs to be coordinated at both the national and regional levels (*8, 9*). African states have realized the scientific value and practical economics of such regional bodies, and have now established the Scientific, Technical, and Research Commission of the Organization of African Unity, the successor body to the former colonial Scientific Council for Africa South of the Sahara. But it is still a weak body and does not yet function beyond organizing international conferences or serving as a documentation institute.

These policy-making bodies can only serve as an infrastructure for ensuring that good and relevant scientific research is performed. What should be our priorities in research? This is a field of inquiry in which detailed discussions have rarely been made in Africa (*29*). It is clear that agricultural production for food and export is bound to dominate our research priorities (Table 4). It is also clear that the prevalence of tropical and vector-borne diseases are a killing and debilitating factor in Africa. At the same time it is recognized that industrialization programs are essential for the widening of the economic bases of African states.

Taking all these into account, it seems to me that our priorities in research for the immediate future should be:

1) Complete inventory of human and natural resources.

2) Intense study of the biology of insects, and similar studies on other arthropods (particularly ticks).

3) Concerted investigation of some of the major tropical human and animal diseases (bilharzia, trypanosomiasis, some types of cancer, malnutrition, and East Coast Fever).

4) Productivity and breeding programs for grain crops.

5) New sources of energy, such as solar energy (a field which is neglected in an area where there may be up to 3000 hours of sunshine a year, giving about 2700 to 4000 calories per square inch per day at ground level).

6) Soil science.

7) Oceanography.

This is a formidable list, and with Africa's present resources in scientific personnel (Table 2), it would hardly be feasible if the individual countries worked in isolation. This brings me to my last point.

Concentrated Research Centers

It seems to me that Africa's best long-term solution to the problems of conducting effective research is to concentrate research effort in a few very large centers. To take one example, for research in insect biology, one could imagine the establishment of a large institute in a locale where other ecological conditions are accessible. It would have a small permanent staff, but would draw a large number of postgraduate students and other researchers from many countries representing many disciplines (ecology, taxonomy, physiology, biochemistry, toxicology, and others). The institute's program would be such that it would concentrate all its resources on a few particular problems over a period, thus insuring immediate returns from the funds invested in it. One can see the influence of such large "centers of excellence" reverberating throughout the few countries where it has been tried—the Weizmann Institute of Science in Israel, the Molecular Biology Unit in Cambridge, England, and the Pasteur Institute in Paris, France. At such centers expensive equipment can be put to best advantage, and the centers offer opportunities for periodical renovation of one's scientific outlook. But above all, they are powerhouses for the initiated and for those wishing to be initiated in research.

I would like to end this article by recalling the words of Malcolm S. Adiseshiah, Deputy Director-General of UNESCO, at the closing session of the Lagos Conference. He stated that "political independence without scientific knowledge and competence is as contradictory as the concept of a vegetarian tiger."

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3. "Free fundamental research" may be briefly explained as pure research, while "oriented fundamental research" may be described as pure research pursued in relation to some practical problem. In this context, "applied research" refers to investigations strictly directed toward some practical problem of immediate national importance.
4. The East African states became independent on the following dates: Tanganyika, 9 December 1961; Uganda, 9 October 1962; Zanzibar, 10 December 1963; and Kenya, 12 December 1963. Subsequently, an armed revolt in Zanzibar on 12 January 1964 led to the merger of Zanzibar and Tanganyika into the United Republic of Tanzania in April 1964.
5. This is most clearly seen in the latest comprehensive review of University of East Africa requirements: D. Nicol, *Report of the Committee on Needs and Priorities of the University of East Africa* (Kampala, mimeographed, 1963).
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16. W. T. Martin and J. L. Aldrich, in *ESI Quarterly Report* (Educational Services Incorporated, Watertown, Massachusetts, Summer–Fall 1965), p. 107. A similar program to the African Mathematics Program was launched in February 1965 at Kano, Nigeria, in primary science.
17. The latest instance of this is the recently published book for secondary schools by Z. Subarsky, *The Living Plant: An Introduction for African Secondary Schools* (Arnold London, 1967). The author was formerly Program Specialist in Biology at the Nairobi Science Teaching Centre, Kenya.
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19. This does not mean, of course, that he is not a good observer of Nature.
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21. T. R. Odhiambo, in *Research Priorities for East Africa* (East African Publishing House, Nairobi, 1966), p. 11.
22. B. A. Ogot, *Afr. Stud.* **20**, 123 (1961).
23. The Nilotes inhabit a large part of East and Central Africa, including the Sudan, Ethiopia, the two Congos, the Central African Republic, Chad, Angola, and Mozambique. Their original African home is thought to be along the banks of the river Nile. They have intermarried in various degrees with the Bantu peoples, but they still retain a distinctive cultural heritage. They perhaps number some 30 to 40 million people, but this is at best a guess.
24. P. Tempels, *Bantu Philosophy* (Présence Africaine, Paris, 1959).
25. J. Jahn, *Muntu: An Outline of Neo-African Culture* (Faber and Faber, London, 1961).
26. I have deliberately simplified the whole statement of the African philosophical system in order to bring out the stark differences between it and other world philosophical systems. There is no doubt that a deeper study of African philosophy will, among other things, enrich discussions on science teaching problems and public understanding of science in Africa.
27. For a summary, see *Bull. Reg. Centre Sci. Technol. Afr.* **1**, 3 (1967).
28. The United Arab Republic has a Ministry of Scientific Research which, among other things, organizes scientific conferences and training courses, organizes state prizes for science and in other ways encourages scientific research. It has established information and documentation services, fosters and supports the activities of scientific societies, is responsible for the successful accomplishment of the national research programs associated with the national development plan, and is the main advisory body to the government on science policy.
29. The East African Academy has made the first such effort recently when it convened a 4-day seminar of research directors, university researchers, and government leaders in February 1966 in Nairobi, Kenya. The theme of the seminar was "Priorities in Biological Research." Papers presented at the conference have been published as *Research Priorities for East Africa,* R. A. Garver, Ed. (East African Publishing House, Nairobi, 1966).
30. R. H. Green, *J. Mod. Afr. Stud.* **3**, 249 (1965).

31. I thank the East African Common Services Organization for allowing me to submit the two photographs.