13. TOWARDS AN EPIDEMIOLOGICAL APPROACH

Epidemiology is the cornerstone to plan and manage control programmes of diseases having public health importance and for community oriented primary care. Its focus of attention reaches beyond the health of individuals and addresses the health problems of a whole community or region.

Epidemiology was born out of the need to describe and to control communicable diseases of which the most threatening are endemic in tropical regions. The Broadstreet pump cholera episode in London, in which John Snow (1854) identified a particular waterfront to be the source of the epidemic and proved thereby cholera’s water-borne transmission, highlighted the value of the epidemiological method. This novel approach promoted the systematic search for the origins and mechanisms of disease transmission. It took advantage of advances in microbiology, parasitology and entomology. The tropical regions, rich in vectors, were ideally suited for the research on transmission of malaria, sleeping sickness, schistosomiasis, arboviruses, etc.

Field and laboratory data had been accumulated over many years and were subjected to statistical analysis. Very quickly it became clear that the quality of the available figures was doubtful. Statisticians and physicians joined forces to develop rigorous statistical methods to get reliable and representative data.

At first it became evident that the only available descriptive figures of prevalence and incidence of a specific disease, even if based on reliable data, could not make it possible to obtain a true situation analysis. It was necessary to get a global picture, taking into account determinants such as immune and nutritional status, vaccination coverage, heredity, lifestyle, migration, housing, occupation, type of setting (urban, suburban, or rural), socio-economic conditions, and the environment.

Until the middle of this century, the focus of attention of epidemiologists remained restricted to infectious diseases; since the forties it was gradually extended to non-infectious medical problems and to disabilities, such as cancer, Kaposi’s sarcoma, diabetes, hypertension, eclampsia, atherosclerosis, and disasters.

For many of these health problems there was no proven cause nor a clearly defined causal mechanism. To establish causality, all non experimental epidemiological work had to face up to the issue of defeat. To get away with such embarrassing distortions, novel statistical and epidemiological design and analysis methods had to be developed. Over the past 25 years an enormous development of quantitative methods could take place thanks to the newly available computer support.

Personal computers allowed the epidemiologists to increase the sample size of the population and the number of variables studied, by means of more complex statistical treatment. Very quickly it became evident that the wealth of numerical information was only part of the answer and that prior conceptualization and classification of data was necessary. This became the basis of epidemiological modelling, which is progressing slowly and is accepted as an important contribution in the tropical environment.

In the last decade people began to realize that the health care system itself can be a major risk factor for the health of individuals as well as for the communities. Therefore community oriented primary care was developed, in which epidemiology played a fundamental role in the planning, monitoring and assessment of health care programmes and services. The premise of this approach is that a larger availability of data and an intensive use of epidemiological methods provided a rational basis for decision-making about health, in order to contribute to the improvement of health and even to the general development.

Since the WHO meeting at Alma Ata in 1978 a trend has been set to integrate vertical programmes into the basic health services. As polyvalent health workers have to control the endemic diseases, there is a need for objective clinical algorithms and for curative strategies. The need to rationalize clinical decision-making, led to the development of a particular branch of epidemiology: clinical epidemiology. The constantly increasing number of courses in epidemiology underlines its growing importance. The fundamental issue of such training is not so much the transfer of knowledge and skills, but rather to encourage students to inspire their planning and management of vertical and horizontal programmes and services.

Epidemiology has to handle information, to establish health profiles, and to determine causal factors, and therefore it cannot be considered as a separate, autonomous scientific field. By definition it covers a large field of observations and promotes interdisciplinarity. By enabling to fix health priorities it contributes to optimize control programme’s and community based primary care to control health hazards.
THE CONTRIBUTION OF EPIDEMIOLOGY TO STUDY AND CONTROL PUBLIC HEALTH PROBLEMS

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1. Epidemiology as biological and social science

1.1. Evolution of thoughts

Epidemiology is the study of the distribution and determinants of diseases and disorders in human populations. Epidemiological studies are either purely descriptive, that is limited to the description of the distribution and the spread of a disease in a given environment, or analytic in searching for aetiological factors, in this case they include retrospective and prospective data on the association between disease or exposure to infection. There are, of course, hybrid designs, both descriptive and analytic (Anderson and Mantel, 1983); the ambidirectional design is the combination of an initial description, a prospective follow-up of a minimal number of factors, and a nested case control design based on incident cases; an example of such a study-design has been worked out for Chagas’ disease (De Muynck, 1984). There are also experimental designs, which want to prove the effects of man-made interventions on the environment, and of any other exposure that can be influenced by mankind.

Nowadays epidemiology became quite a popular science as shown by the proliferation of epidemiological summer and graduate courses, books and journals (Vandenbroucke, 1990). Epidemiology can be considered as a methodology as well as a body of knowledge (Lilienfeld, 1984). It was born out of the need to describe communicable diseases and to optimize their control. Some schools consider John Graunt, who lived in the seventeenth century in the UK, as the father of this discipline (Rothman 1981), but it is only in the middle of last century that this discipline started to make real contributions to community health. The turning point was the Broadstreet pump cholera episode in 1854 in London, in which John Snow used for the first time the germ theory of disease to explain the spread of cholera; his theory was confirmed through statistical data (Cameron and Jones 1983). His approach highlighted the value of epidemiological methods and showed that epidemiologists could be even ahead of microbiologists in the search for causality.

At the end of the last century epidemiology took advantage of the progress made in microbiology, parasitology and entomology. Until the middle of the twentieth century epidemiology was focusing almost exclusively on infectious diseases. Such a pre-modern epidemiology had as primary aim to solve health problems, to prevent and control infectious diseases. By restricting epidemiology to infectious diseases, the epidemiologist’s scope is too narrow as it excludes many medical problems such as primary liver cancer, Burkitt’s tumour, Kaposi’s sarcoma, haemoglobin disorders, various forms of heart disease and malnutrition prevailing in Africa.

In recent years epidemiology has extended its focus of attention and has moved towards health care planning (Waters 1979), resource allocation and even health care delivery (Evans and Brachman 1986).

The medical practitioner attempts to identify his patient’s disease by determining its aetiology, and then tries to control the disorder by an appropriate treatment. The epidemiologist’s objectives and concerns are quite similar, but they focus on the community rather than on individuals. Epidemiology goes beyond the disease itself in search for preclinical stages, for carriers of pathogens or for antibodies. Relevant statistics are collected on the entire community, to evaluate the available curative, preventive and health promoting services, and to enable the setting of priorities as to plan adequately and organize control programmes. In doing so, the epidemiologists might even discover unexpected links between causal factors, thereby increasing the chances of an effective control.

There is no better way to emphasize the contribution of epidemiology than by recalling that it has been able to produce valid methods to interrupt the spread of a disease even before its aetiological factors had been discovered. Cholera, malaria, scurvy, congenital malformations caused by German measles, and retrolental fibroplasia are examples of the control of diseases thanks to epidemiological data, before the agent had been recognized.

1.2. The epidemiological transition in Third World countries

The burden of disease in a community has to be estimated in a framework that considers not only the fact that he has to recognize the major health problems, and the capacity of the health system to deal with them, but also to identify the environmental, social, economic and political context of ill-health. In most developing countries the health picture is rapidly changing from an infectious disease profile, to a predominantly non-infectious one. Omran (1971) called this the epidemiological transition.

A first determinant of this transition is the demographic change, largely driven by the mortality and the fertility decline (Sinding, 1991). As a consequence, the health services have to place major emphasis on the rapidly increasing young population strata and older adults who have each their specific health problems.

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As a second determinant of the transition one has to evoke the major social and economic changes, which are transforming the epidemiological risk factors themselves (Roemer and Roemer 1990). A clear indicator is the reduction in risk for infectious diseases associated with the shift from rural to urban living, as there is on the whole a better waste disposal, safer water supply, and higher vaccination coverage. An exception has to be made for the poverty belts of the peri-urban slums, where overcrowding and disruption of traditional rules of sanitation, lead to a poorer health status than in rural areas (De Carneri et al., 1993). On the other hand, urbanisation brings new health problems as for example the rising homicide rate (Van Geldermalsen and Van der Stuyft, 1993), chronic diseases and health problems related to the weakening of social networks and family ties. AIDS is a recent illustration of disease transmission in Africa facilitated by development strategies that favour males for urban employment (Over and Piot, 1991).

In the developing world the epidemiological transition is neither a steady nor a uniform process. Wide disparities in health conditions are observed across different social classes or regions of each country. These disparities are not limited to infectious diseases, nor to children, but include also chronic diseases prevailing in adults (Feachem et al., 1991). The developing countries have to deal with these two kinds of problems at the same time (Foege and Henderson, 1986), although with changes in relative importance occurring over the years. Brazil is an example of a country with an incomplete epidemiological transition (Prata, 1992). The challenge for the developing countries is to develop equitable health policies and strategies to meet these new conditions (Jamison and Mosley, 1991). Epidemiology can and should play a key role in that equitable development and in the monitoring and assessment of their implementation.

1.3. The contribution of epidemiology to control diseases and to plan and manage health services

There is general agreement that vertical control programmes need a sound epidemiological base. In the various phases of the development, implementation, monitoring and assessment of such programmes, epidemiological data are the cornerstone of decision making. Assessment of the impact of a vertical programme is essential for strategic management and for continuous donor commitment. A valid impact assessment needs a precise initial epidemiological profile, reliable surveillance data and a good knowledge of the potential confounders, in order to be able to answer the question of what should have been the evolution of the endemcity without that particular control programme.

The contribution of epidemiology to health service management and planning is still rather controversial. Some schools doubt that epidemiology can make a pertinent contribution: they argue that the organization of polyvalent services is insensitive to variations in the prevalence of diseases; according to the representatives of those schools, impact evaluation is lacking relevance and efficiency (Unger and Dujardin 1992).

Other schools, however, consider epidemiology to play an essential role in the management and planning of primary health care. The basic controversy between these approaches is their main focus of attention: the first schools take the health service organization as a goal by itself; the second schools develop community health programmes according to the health needs of the target community, as determined by epidemiological appraisal (Abramson 1984, Foz et al., 1991).

In community oriented primary care, epidemiology is involved at all stages of the health care system: not only in the appraisal of needs and demands, in the community diagnosis, in the formulation of programme objectives and in the choice of strategies, but also in the selection of target groups and in the implementation, monitoring and assessment of the programmes; and, last but not least, in the epidemiological surveillance of the health of the community and in stimulating the community’s involvement.

The epidemiological orientation in Community Oriented Primary Care is very much applied: the epidemiological work is carried out in the Community itself; is focused on the specific problems of the community, and aims to optimize the health of the community through the application of the results of the epidemiological observations made in that community (Abramson, 1984a). A basic requirement of this community oriented primary care is a field and process oriented teaching of epidemiology. Further more the medical personnel needs to be fully aware of the role of the community in health development (Macfarlane et al., 1993).

2. The epidemiology of communicable diseases in Central Africa

Surveying the occurrence and/or spread of major health problems and diseases in a country or a region
TOWARDS AN EPIDEMIOLOGICAL APPROACH

does not, by itself, provide a comprehensive basis to plan appropriate medical interventions. The determinant factors of the incidence and spread of the health problems must also be recognized. The physicians working in the tropics have very quickly grasped the need for such a broad approach and have realized that the combined approach to man and his environment of a naturalist and a physician is the solution. This comprehensive approach is in fact epidemiology.

The epidemiologist’s knowledge on communicable diseases largely benefits from an accurate understanding of the environment. The in-depth study of living beings within their own biotope gives further insight in the transmission mechanism. The ecological niches vary greatly in size, and combine relatively stable physical, chemical, climatic, and biological features: grassy savannahs, shrub savannahs, thick forests, forests-corridors, mangrove swamps, etc. Each of these environments harbours associations of plants and animals which were constituted over centuries or millennia. A natural focus may be as precise as the source of a stream, a lake, a forest canopy, a ravine – all meeting places for pathogenic microbes, animal reservoirs, arthropods and molluscs; the established associations may or may not be further influenced by human activities.

These systems are constantly subject to the influence of factors which shape the environment, such as climate (temperature, hygrometry, rainfall, barometric pressure, insolation, wind), structure and chemical composition of the soil, and physical and chemical qualities of water, determined by its origin and the passage of its flow.

The first explorers, travellers, merchants and missionaries to venture overseas were struck by the extreme complexity of the new regions which they reached. The (often scanty) information they reported appears in travellers’ chronicles rather than in the medical literature of that time.

The discoveries of the microbial and parasitic agents of infectious diseases tended to overshadow a more global environmental study. Generations of physicians in the northern hemisphere had tried to unravel the complexity of the communicable disease transmission through careful observation of the environment. While those studies did not answer the questions of disease transmission, they did, however, provide a wealth of information about the environment. It is a pity that this tradition is not given similar importance in today’s approach to public health problems.

The first physicians to arrive in the tropics quickly realized that an aetiological approach limited to germs and parasites rarely provides the right information; today, their successors still remain aware of that fact.

The occurrence and evolution of diseases depend on a wide range of factors, both biotic and abiotic, some of which are playing an indirect or even a direct role.

Communicable diseases caused by biotic factors, continue to head the list of medical problems in tropical Africa. However, their occurrence figures may show big variations, even over very short periods of time. Each host-parasite-vector system, and the natural foci, are constantly changing. These dynamics are not a product of chance, they are regulated by very specific factors.

There is a strong tendency to reduce the epidemiological system of human communicable diseases to the triad pathogen-vector-man but the factors are actually much more numerous and their relationships far more complex.

Indeed the biotic or living edifice encompasses the entire biosphere of plants, animals, and man.

The abiotic (or physical) environment consists of the climate (temperature, rainfall, humidity and oro-hydro-topographical conditions) as well as of the geo-morphological conditions of the region (edaphic or physico-chemical properties and texture of the soil). These parameters can be altered by human activity, such as forest clearing, dam-building, irrigation and drainage of marshes. It should be borne in mind that man, being endowed with an innate sense of conquest and domination, does not feel tied up to a given biotope but constantly modifies the environment according to his needs.

Large-scale disturbances are caused by major geological events, such as the continental drift extending over large geological eras. A very instructive example for tropical Africa is the site known as the Rift Valley and its lakes; these are vestiges of the sea that separated East Africa from the African shield 100 million years ago; the two parts were not united until the beginning of the Tertiary period, 30 million years ago. That long period of isolation led the flora and fauna to evolve separately on either side of the depression; significant differences still remain, for mutual invasions and crossbreeding have occurred only very slowly. This dichotomy is well illustrated by the two human trypanosomiasis species: Trypanosoma b. gambiense and Trypanosoma b. rhodesiense.

The small lake that was cut off from Bobandana Bay (Kivu) by a lava flow, is a recent example of this type of geological accident. The result was the creation of a breeding ground for Anopheles mosquitoes leading to an active malaria focus.
2.1. The human host

Man colonized most of the planet as he was evolving into Homo sapiens. The shift from a primitive hunter-gatherer lifestyle and an economy based on gathering, to an agricultural economy together with the domestication of animals which satisfied most of man's basic needs of nourishment and led nomadic people to become sedentary. Today a minority of the world's population has remained devoted to nomadism, such as shepherds who must move their animals to new pastures when the old ones are exhausted. A few small groups have maintained a lifestyle that combines nomadism and food gathering, meagerly supplemented by a limited trading of food-stuffs with settled communities in the region.

Sedentism by itself creates new biotopes. Human beings, animals, dwellings and stores attract a variety of insects which then become settled once they find the occasional and regular sources of blood needed for their nourishment. Rodents are also drawn to these abundant food supplies, and various species become domestic or peri-domestic.

Rotating cultivation increases the environmental changes and the risks of encountering new pathogens.

The ecological problems vary greatly from savannah to forest. Both habitats are characterized by poor tropical soils and mediocre yields.

In the savannah, where irregularities of the climate and especially erratic rainfalls create very precarious situations, farmers must alternate crops and fallows, but also clear either new plots or places which were left fallow for variable periods of time; consequently a number of ecological habitats are modified. One particularity of that agricultural system is the cultivation of hillslides and mountainsides which have to be terraced to limit erosion. The terraces are separated by low walls, strips of tussock grasses or even bush; and these unfarmed strips are ideal places for rodents to burrow and build nests. Such a biotope increases the risks of infection in plague endemic areas.

In the forest, trees must be felled to clear land for new settlements. Deforestation often occurs on a large scale if roads, telegraph and power lines are built, or forestry, farming, mining and industrial activities are introduced; all of which lead to the creation of new biotopes and new risks of infection. Felling trees brings an extraordinarily rich habitat of the forest canopy, usually inaccessible to man, into contact with the ground. These canopies harbor wild insects that maintain transmission cycles, especially those of viruses and animal diseases; and a new chain of transmission may start, possibly pathogenic to man, when for example a woodcutter felling a tree is bitten by a mosquito displaced from its canopy. This is for instance the pattern of transmission of yellow fever arboviruses.

In their daily activities men, women and children come into contact with various vectors in their natural habitats. For example tsetse flies having elected shaded ecotones near watercourses and springs as areas of activity, will feed on people who visit such sites. The same is true for black flies that live near rapids and fords.

Modern agriculture makes great use of irrigation and even of flooded fields. Water management includes the creation of dams of various sizes. The smallest of these dams are often the most dangerous for human health, because of the concentration of vectors (both insects and molluscs) and the risks of contamination by repeated contacts.

Nomads have made the choice of a specific lifestyle: only major catastrophes can force them to abandon their ancestral way of living in favour of a sedentary style that they hope will be only temporary. The search for richer land and greener pastures led to migrations that were undoubtedly slow, but extended for very long periods of time and over immense distances. The various stages of this evolution are still found today in isolated communities.

In the course of this evolution, man came in contact with a wide range of biotopes and natural vectors, eliminating some, but also creating new ones which became habitats for the vectors. Human activities contribute directly to the presence or elimination of various vectors, for example a high human population density is sufficient to eliminate certain tsetse flies. In contrast, the choice of a new plant variety, the Lantana camara, for an enclosure around the homesteads, offered a new habitat for G. fuscipes and promoted the transmission of T. b. rhodesiense (Okoth, 1986).

The site on which a village is built is also important; for example a location at the edge of a forest or a forest-corridor increases the likelihood of encountering vectors. Chrysops, the fly which is the vector of loa loa, is attracted to certain areas by human activities.

Moreover man has greatly changed his way of life, in terms of dwellings, clothing, food and occupations. Urbanization is the biggest alteration. The hypertro-
phy of human settlements, with as extreme the modern megalopolis, leads to profound changes in lifestyle and human relations, as well as to the disintegration of ancestral socio-cultural traditions, sometimes even leading to their complete collapse. The gradual weakening of traditional ties has a definite effect on the mental balance of the individual. Moreover the extension of residential neighbourhoods modifies the ecosystem: natural habitats disappear as do the wild rodents, unless the galloping urbanization still retains some rural pockets, even temporary ones, which may be sufficient to allow interurban transmission of African sleeping sickness as seen in Brazzaville (Gouteux et al., 1986) and other African cities. On the other hand, urbanization causes the domestic rodent population to increase and can even create new breeding grounds for mosquitoes. Garbage collection is rarely satisfactory, drainage is often far from perfect, and the tin cans, shards, old tires and other receptacles constitute multiple habitats for mosquitoes.

The population density, occupational, trade and markets, leisure activities and mass transportation, all increase the likelihood of direct or aerosol transmission and the risks linked to the maintenance of pathogenic complexes.

Man is not an indifferent host; some of his genetic traits may render him refractory or much less vulnerable to certain infectious agents. For example the absence of Duffy’s antigen hampers the development of Plasmodium vivax, while the Sickle cell trait affords protection against P. falciparum. The impact of these blood groups and of HLA characteristics justifies in-depth research into their contributions to the genesis of receptive or refractory states.

One may not overlook the immune defences that determine the subject’s receptiveness to pathogens. Indeed, when an infection rages in a community, some subjects may remain uninfected. This resistance may be due to some natural immunity, which would explain why some zoonoses are never transmitted to man, or may be linked to specific personal immunity, either absolute or partial, permanent (such as for yellow fever, measles) or temporary (dengue fever, flu). This immunity may be acquired, naturally or actively, through a previous and perhaps clinically undetected infection, or artificially through administration of vaccines, immunosera or specific gamma globulin. The immunity will persist as long as the specific antibodies are present.

In malarial holo-endemic areas, plasmodia in the blood may indicate premunition or tolerance. Detecting them in the blood of a patient, even a feverish one, is of no immediate diagnostic value, for an intercurrent disease can weaken the tolerance and momentarily upset whatever equilibrium has been achieved. By contrast, the presence of these same plasmodia in the blood of subjects from non-endemic areas is not only highly significant but can even indicate the need for urgent treatment.

The main mechanism to create artificial immunity is vaccination, either with attenuated living germs (yellow fever, measles, etc.) or with killed germs or toxoids (tetanus, diphtheria). These inoculations trigger the synthesis of specific glycoproteins or immunoglobulins (Ig) by the competent cells. Premunition (or immunizing infection) is a special case. The recovery of subjects who have contracted certain infectious diseases, does not mean that they no longer are germ carriers, for pathogens may persist in a latent state in their body and, through their presence, protect the subject from reinfection by the same pathogen. This is the case for certain helminths the presence of which limits reinfection; also for brucellosis, tuberculosis, and malaria, in which case there is a resistance to an infection which is neither too frequent nor too severe. These balances are precarious and cannot withstand factors that undermine resistance, such as fatigue, disease or malnutrition.

The particular problem of neonatal resistance to certain diseases is linked to the presence of antibodies in pregnant women, that can cross the placental barrier or be secreted in the mother’s milk. Such a protection may be provoked deliberately to prevent neonatal tetanus by vaccination of the mother, but the protection does not persist beyond the third month and moreover is limited to gamma globulin (IgG). IgA and IgM cannot be communicated, which explains the high sensitivity of newborns to E. coli, Salmonella, and Shigella.

There are various factors that influence receptiveness, including substances such as interferon, lysozyme, properdin, opsonin or other similar products which have no real immune activity. But age, sex, presence of abnormal haemoglobins, hereditary factors and G-6-PD deficiencies must also be taken into account.

Nomads, pilgrims, refugees, displaced persons, migrants and seasonal labourers are all highly receptive; they constitute additional sources of new pathogens, and increase the spread of infections and their vectors. This is the case for rickettsiae and lice. People arriving in the area often increase the virulence
of the pathogens through a combination of rapid passage and greater receptivity to new germs, which they further spread into the community.

2.2. The environment

The vegetation determines to a great extent the ecology of a region. There are various phyto-ecological units such as forests, patchy transitional savannah, marshlands, mangrove swamps, reforested areas, plantations, and plots for food and industrial crops. Their profile depends on the soil, the altitude, the temperature, the watercourses and the lakes.

The environment is subject to major changes, occurring more and more frequently, such as deforestation, erosion, desertification, man-made lakes, dams, irrigation networks, more aggressive herding and farming techniques, flooded rice cultivation, ranching and fish farming. Due to these interventions the natural environment is permanently deteriorating.

The vegetation is that part of the ecosystem that is most exposed to the changes made by man to his environment while he adapts it to his needs. Such meddling is a human characteristic. When the forest-dweller switches from gathering to subsistence farming, he must clear enough land for his house and fields to grow grain, tubers and bananas. Due to the rapid impoverishment of the forest soils, new land has continuously to be cleared. This disrupts the biotope and increases contacts with arthropods, rodents and other forest animals that carry their own parasites. This centuries-old process does eventually reach a new equilibrium.

Economic development accelerates these changes, which often culminate in real environmental disturbances. The damage to the plant cover increases contacts between man and the invertebrates or vertebrates, and also offers to vectors new biotopes that are more or less suitable as breeding grounds.

But man’s contributions to the flora are not only destructive. He also plants, reforests, introduces new and more productive varieties, improves and modernizes farming methods, uses fertilizers and pesticides. Each of these interventions, however, leads to new problems, some of which are medical.

2.3. The animal reservoir

Vertebrates act as reservoirs, intermediate hosts and/or amplifiers. As hosts for parasites they contribute, through their mobility, to the spread, amplification, and transmission of harmful germs. Zoonoses may also spread to men. Animals are carriers of germs that are pathogenic to humans. Man may inadvertently enter a transmission cycle that is specific for a given animal species (as is the case in rodent plague and canine leishmaniasis) or become part of the cycle of a parasite such as is the case for T. b. rhodesiense trypanosomiasis or toxoplasmosis.

The list of animals linked to this type of transmission is almost endless. Pets and farm animals constitute the biggest risk for man. Dogs can be potential carriers of more than fifty different diseases, but also cats, horses, cattle, pigs, sheep, goats, barnyard fowl, ornamental birds and house rodents (rats and mice) are transmitting diseases to man. Pet animals are the most dangerous, given their regular contacts with people; their excrement, fur, claws, etc. are sources of various risks.

Wild monkeys and dogs, jackals, hyenas, warthogs and bats, as well as terrestrial, arboreal, domestic or peridomestic rodents, are the reservoirs of plague and tularemia. Warthog beef and especially hippopotamus meat may be infected with B. anthracis, and may thus be at the origin of malignant pustules and pulmonary or systemic anthrax. Bats can transmit rabies through their bites.

The migrations of mammals and birds are important for the spread of certain diseases. Migratory birds usually follow more or less regular routes and spread viruses and ectoparasites. This is particularly true for the birds from the Southern and Northern Hemispheres that alternately occupy the same nests on small Central African lakes.

The number and variety of pathogens and parasites carried by animals are just as impressive, and embrace all domains. Examples of helminthiasis are tapeworm infections, distomatosis, echinococcosis and larva migrans cutanea. Protozoal zoonoses include leishmaniasis, toxoplasmosis, trypanosomiasis, balantidiasis and the simian plasmodia. Bacterial infections encompass practically the entire range of pathogens, and include tetanus, anthrax, Salmonella infections, brucellosis, tuberculosis, the vibrio diseases, plague, tularaemia, leptospirosis, Borrelia infections, chlamydial and rickettsial infections (especially spotted fever, Q fever, and rickettsial pox); viral infections such as rabies, lymphocytic choriomeningitis, Rift Valley Fever, monkey pox, cat-scratch fever, avian diseases, yellow fever, and arbovirus infections are also harboured by animals; mycoses such as actinomycosis, aspergillosis, histoplasmosis, cryptococcosis, nocard-
diagnosis, bovine and avian tuberculosis, cutaneous streptotrichosis, and tinea are carried by animals, as are arthropod infestations, sarcotic infestations (scabies), and skin diseases caused by acarins, *Hypoderma bovis*, and the Oestridae. The list is impressive, although far from exhaustive.

There are various modes of contamination, predominantly by excrements, or through contact with hair and fur. Germs and spores may be present on the hides, hairs, and wool. A specific example of such a contamination is the transmission of *Coxiella burnetii*, which corresponds to the calving period. In this system, the fresh or dried blood of the afterbirth from infected cows, contaminates the environment with infective organisms, that readily become airborne in dust. In contrast, there are other diseases, such as aphthous fever (foot and mouth disease), that seldom infect man.

The animal kingdom is also subject to serious disruptions by man’s interventions. It is difficult to halt the extermination of certain species with commercially valuable attributes (elephant tusks, rhinoceros horn, crocodile skin, etc.); hunting with automatic rifles to supply markets with meat and skins is also contributing to the extermination.

2.4. The vectors

The catalogue of vectors contains a large number of invertebrates such as mosquitoes, lice, fleas, ticks, tsetse, *Chrysops*, black flies and sandflies. For each arthropod vector the medically-important representatives have been identified. The main group, the Culicidae family, includes the Anophelinae subfamily, to which the Anopheles mosquitoes belong, some of which are involved in the transmission of malaria. However, since a number of years it has been observed that not all members of a given species transmit the same disease, for example there are instances of Anopheles infestations without malaria. *An. maculipennis* is the first species to have been recognized as a species complex, and its separation into *An. atroparvus* and *An. messeae* was established on biological grounds.

Regarding another important complex, *An. gambiae*, observations made in the field led researchers to suspect the existence of several ecotypes. Purely morphological features are not sufficient to characterize this polymorphism, therefore genetic analysis had to be done. The latter has given evidence of the existence of several varieties of *An. gambiae* (*An. gambiae* ss. *arabiensis*, or ss. *melas*), confirming certain epidemiological findings. The same problem was encountered for other arthropod vectors, such as the *Simulium damnosum* complex, which was subdivided, thanks to cytogenetic analysis, into a large number of cytotypes, some of which (*sirbanum*, *santipauli*, *yehense*, and *squamosum*) are species.

The proven or potential vectors, infected or not, are characterized by an active natural dispersal, usually in a very circumscribed area. However they can be passively dispersed over much greater distances as stay-over on the various means of transportation by land and water, such as the tsetse flies, but also by air. The wind can carry vectors over amazingly large distances; for example, black flies may be carried over hundreds of kilometres.

The transmission of infections by vectors involves complex relationships among the infectious pathogens, virus reservoirs and hosts.

The vectors are infected while seeking food, which usually means a bloodmeal or sometimes absorption of tegumentary fluids. The moment of contact depends on the vector’s diurnal, crepuscular, or nocturnal activity. Infection of the vector depends on the concomitant presence of infectious agents in the host. In addition, there is a density threshold for the infective material, below which infection aborts. The infection of vertebrates depends on the presence of sufficiently high numbers of infective forms in the vector.

Relationships between the vectors and infectious agents vary according to their feeding pattern. Blood is certainly the only food that provides many arthropods with the indispensable elements, notably those required for the development of the female anopheline mosquitoes’ gonads. Some male arthropods have remained vegetarian. There are carnivore larvae the stomach of which contains a peritrophic membrane that surrounds the blood meal and captures most of the pathogens. Those that escape ensure the continuation of the infectious cycle.

The vectors must allow various viruses, bacteriae and rickettsiae to multiply. This is very important in the case of viruses, which will disseminate into the organs, including the salivary glands and ovaries. The latter site offers the possibility of transovarian transmission, also called vertical transmission, especially of certain arboviruses, of *Borrelia* (in *Ornithodorus* ticks), and of rickettsiae. Transmission may even occur between consecutive stages of the Ixodidae. Such arthropods become reservoirs for the pathogens.
For some protozoa the passage through the vector must allow the continuation of the sexual reproductive cycle, that consists of a series of phases, starting when the protozoon escapes the peritoneal membrane to ensure the transformation into infectious forms that are found in the excrements, secretions (fluids and coxal secretions), in regurgitated material, mouth pieces, and even in the salivary glands and saliva. This transformation may or may not involve reproduction. Filarial parasites turn into infective forms without any multiplication.

There are various modes of transmission: purely mechanical transmission may occur, but the main transmission is biological. The latter may be subject to a complex set of conditions, for example the vectors may encounter mechanical, physico-chemical, cellular or genetic barriers, preventing the survival of the parasites in the intestine, the body fluids or the salivary system.

Inoculation occurs through a wide variety of mechanisms, such as interrupted feeding on an infected host followed by the resumption of feeding on a new, uninfected host. One should remember that feeding is usually accompanied by excretion of waste. Contamination by excrements or infected mouth parts or the coxal fluid of the insect cause reflex scratching of itchy areas which enables the infective forms to enter through the damaged tissues, etc. The *Thrombidiidae* lacerate the epidermis with their mouth pieces.

The vectorial capacity of the vectors may vary. The variety and density of vectors in the environment play decisive roles. Moreover the host itself will be infected only above a certain infectivity threshold.

The vectorial system is urban, rural or sylvatic; it depends on the ecological conditions. The biotope may be the tops of large trees, as in the case of arbovirus infections, or may be located at ground level (in the case of cutaneous leishmaniasis), along waterways and on the edges of wells and drinking holes, or even inside the homesteads.

Unplanned urban extensions lead to the inclusion of islands of rural ecotopes within the urban limits, this explains how an epidemic of intestinal schistosomiasis occurred in the megalopolis of São Paulo. However, urban ecosystems, such as those of *Aedes aegypti* and *Culex pipiens fatigans* exist also.

The irrational, and sometimes even irresponsible, use of pesticides and insecticides may disrupt the natural equilibrium; their effects may be intensified by the disappearance of predators, which have a vital regulatory role. A typical example of such a bio-ecological deregulation caused by insecticides was observed in Kinshasa where after large aerial sprays of DDT huge numbers of flies developed from larvae which proliferated in the open sewers: indiscriminate spraying had changed the ecological conditions in the sewers, making them more favourable for the hatching of adult flies. Today this plague is still hard to control in Kinshasa.

*Palaeo-entomology* combines palaeontology and entomology. It developed first in central Europe, but shifted afterwards to the United States, Australia and to the Soviet Union. The importance of this discipline can be illustrated by Cockerell’s discovery (1907-1919) at Florissant, Colorado, of fossilized imprints of four forms of tsetse flies, one of which was *Glossina oligacena*, in volcanic ash layers dating back to the Miocene. This gave rise to speculations about the possible causes of the disappearance of tsetse flies in the New World and of their absence in Asia and Australia.

The climatic and ecological conditions leading to the disappearance of *Glossinidae* during the Pleistocene were probably the same as those that confined the genus to their current spread in tropical Africa. Such basic information is very useful when the persistence of a vector is studied in order to develop a suitable control programme.

The tsetse-*Trypanosoma* association surely influenced the composition of the fauna by selecting tolerant species, which did not fail to include the proto-hominids and hominids. Similar arguments may also apply to other vectors (mosquitoes, ticks, mites, etc.) and reservoirs hosts.

2.5. Pathogens

The pathogens cover a wide range of organisms, from viruses to helminths and the countless related saprophytes. Whether these pathogens be viruses, bacteria, mycetes, protozoa or other parasites, their mobility remains restricted to that of their vectors and/or their infected hosts. This does not rule out long-distance carriage, especially in the current epoch of supersonic travelling.

2.5.1. Biology, virulence, variability and tissular affinity of pathogens

The biology of these pathogens varies enormously, as do their positions in the living world. Some, such as viruses, reproduce only inside hosts or vectors: others,
such as bacteria, multiply in a variety of settings; others still, such as some helminths, reproduce within a cycle that involves one or sometimes even two intermediate hosts.

Their virulence (or capacity to cause severe disease), their reproductive ability and their aptitude to produce toxins are very relative; a classical example is entamoeba: Entamoeba dysenteriae is present in the gut as a normal commensal, and E. minuta becomes pathogenic only after its transformation into a tissue-invading parasite. The tick-borne rickettsiae provide another example of this variability: R. rickettsii, the causal agent of Rocky Mountain fever, kills between 5% and 80% of its victims; the very closely related R. conorii causes spotted fever, and is responsible for a generally benign disorder, while R. montana, the DNA sequence of which is for 75% homologous to that of R. rickettsii, never infects humans. The tissular affinities of the pathogens are very diverse, and result in rather distinctive lesions that are reflected in the common names given to the diseases they cause. Tissular affinity may be limited to one target organ, include a range of organs, or be caused by toxins. All these possibilities are a function of the presence of structures or substances that bind to specific tissue or cell receptors. They are generally subdivided into dermato-tropic, neuro-tropic, hepato-tropic, and pan-tropic systems. Some agents of disease, including protozoa, rickettsiae and viruses, also lodge in the cells themselves.

2.5.2. The contributions of palaeo-parasitology

An interesting source of knowledge about parasites is the palaeo-parasitology. This branch can contribute to a better understanding of the origins of the current distribution or the biogeography of parasites.

Fossilized material provides strong arguments in favour of the presence of specific parasites, and is sometimes discovered in archaeological excavations. However, the evidence is usually indirect, because the soft tissues neither fossilize nor leave imprints. The presence of endoparasites in early periods of the planet’s history can be deduced from the presence of eggs of intestinal worms in fossilized faecal material (coproliths) and the tissues of well-preserved human remains. In Peru, the United States and China such investigations have been most informative. Unfortunately nothing similar has taken place in Africa, despite the fact that Africa has given the world vital information about the hominids. Ectoparasites (lice, fleas and mites), which outer shells may be fossilized, also provide evidence of the presence of specific parasites.

Parasites account for 60-70% of all infective animals. Their interdependent relationships with their respective hosts and the multitude of adaptive strategies, such as symbiosis, commensalism and mutualism, are realities that cannot be ignored.

Parasites have certainly not reached their final stage of evolution. In any case, opportunistic behaviour is the rule in biology; and parasites continue to evolve at rates generally exceeding the human lifespan. Adaptations over shorter periods can occur through the use of their biological potential. Drug resistance is a good example of this.

2.6. Contamination and transmission

2.6.1. There are numerous living sources of transmission such as the animal reservoir, the vector reservoir, the intermediate hosts, and the human reservoir. The latter may be a patient during the incubation period, a patient in the clinical phase of the disease, a convalescent patient, an individual with an undetected infection, or a “healthy” carrier.

2.6.2. Transmission through a non-living medium takes place by the soil, the air, water and food. The soil is a heterogeneous reservoir containing potentially pathogenic saprophytes, eggs and infective larvae of soil-transmitted helminths, spores of anaerobes and mycetes, protozoal cysts, and bacteria such as the mycobacteria, which are able to survive thanks to a waxy envelope, while meningococci, gonococci and treponemias offer only very little resistance to the environmental conditions.

The air is the carrier for airborne germs and for those transported by aerosols or suspended in dust, such as Koch’s bacillus. Drinking water or the water used in beverages, foods and ice cubes may contain bacteria which cause typhoid fever, salmonellases, vibrio cholera and related pathogens, as well as viruses that cause poliomyelitis, viral hepatitis, etc. Food may be contaminated by water in a variety of ways. The contact with water occurs on various occasions, for example when farming, swimming, washing or bathing, and may be rich in infective larvae such as the cercariae of schistosomiasis.

2.6.3. Portals of entry

a) One of the portals of entry is the skin.

Furcocercariae of the genus Schistosoma burrow into the skin of the swimmer or bather; larvae of hookworm, Toxocara canis, and Toxocara cati also enter via the skin; tetanus lodges in skin wounds, where it produces its powerful toxin; rickettsiae are deposited by lice in their fœcuses to enter as a result of scratching prompted by itching.
b) The mucosae
- the eye membranes are receptive to measles and Q fever pathogens;
- the genital mucosa is the portal of entry for gonococci, Dreyer’s bacillus, Nicolas-Favre’s bacillus, Treponema pallidum (syphilis), herpes virus, Chlamydia and HIV;
- the buccal mucosa is the portal of entry, for example for viral hepatitis and infectious mononucleosis;
- a number of bacteria and viruses enter via the upper respiratory system and lungs. It is the case for the agents of whooping cough, diphtheria and croup, for streptococci, Koch’s bacillus, plague bacillus, Coxiella burnetii, measles virus, influenza viruses, etc.
- the gastro-intestinal tract is the route by which dirty hands, food and drinks introduce into the body a large number of pathogens: geo-helminths, salmonellae, shigellae, cholera vibrios, amoebae, flagellated protozoa.

2.6.4. Exit points
They may be located on the skin or at mucosae of the body’s orifices, such as
- the naso-pharyngeal, buccal and bronchial mucosae;
- the sputum, faecal material and urine;
- the anal and genital mucosae or secretions.
Unclean hands often play a key role in this transmission.

2.6.5. Adaptation
The infective agents have an amazingly high capacity to adapt to changing circumstances. The ability to change their capsule and to rearrange their surface antigens so as to escape the antibodies of their hosts, guarantees their survival in a hostile environment. To keep up with changes in the virus’ antigen system influenza viruses force vaccine manufacturers to change their formulas annually. Infective agents defend themselves against specific treatments by changing their enzyme systems so as to remain unaffected by drugs; hereby they become resistant to medication. Interactions between *T. b. gambiense* and arsenic compounds are a typical example. Infectious pathogens can also adapt to new vectors, as is shown by the adaptation of *T. b. rhodesiense* to Glossina fuscipes in Uganda (Okoth, 1986).

Inf ective pathogens and their vectors are subjected regularly or intermittently to mass drug treatment, immunization campaigns, or to vector control via insecticides or environmental sanitation schemes. When these efforts fail, the known relationships can be modified such as to withstand the usual screening and diagnostic strategies.

3. Community diagnosis

3.1. Contribution of epidemiology to community diagnosis

The term *community diagnosis* refers to the process leading to the identification of the major health problems in a given community, to the definition and ranking of the needs of that community, and to the planning of solutions to those problems, that are relevant, feasible and acceptable to all actors in a community based health care system. The involvement and active participation of the community members is a necessity.

Epidemiology has an essential role to play in the analysis of the situation, and in the empowerment of the communities, but presents some particular features that distinguishes it from the methods and approaches used in infectious and chronic disease epidemiology (Abramson 1984a).

Epidemiological observations in community diagnosis have an eminently particularistic and pragmatic purpose. Relevant data are collected and analysed, to help a given community, residing at a specific place, in a particular environment and at a precise period. This epidemiology is action oriented, and only remotely concerned with the inference of the epidemiological findings beyond the boundaries of time, place and persons of that given community.

The localization of the epidemiological surveys must be situated in the community itself (Aday et al., 1981). Broad ranges of endemicity can occur in a community, as for example the risk of neonatal tetanus; in the Aceh province of Indonesia it was found to range from 2 to 36 per 1,000 live births in the different districts (Yusuf et al., 1986).

The content of epidemiological studies as a base for community diagnosis deals with any topic of great concern to the community itself; and can even focus on the health care system itself (Knox 1979).

The scale of the epidemiological studies for community diagnosis depends on the size of the community served and practical considerations such as efficiency; this particular aspect is a very important criterium in the final choice of the study design to analyse the situation.

Selectivity in the choice of the data to be gathered is necessary, as they have to be highly relevant to the existing or contemplated programmes.
Among the variety of epidemiological data which can be collected in medical settings, a clinical approach serves both clinical and epidemiological purposes, but the inherent selectivity of the study population can be overcome if similar information is obtained from those who did not require the medical services on their own initiative (Abramson 1984b).

3.2. Rapid epidemiological assessment

The classical epidemiological survey methods provide reliable and precise estimates on the occurrence of disease and on exposure factors; however, they are complex, time consuming and rather expensive. In the field there is an increasing need for methods that can accurately, quickly and efficiently assemble the necessary information for community diagnosis and decision making (Asher et al., 1993).

Rapid assessment methods are not new tools as such, but their application to the field of health is novel. In 1989 Smith described five broad types of rapid epidemiological assessment methods: - quick survey and sampling methods, - surveillance methods, - screening and individual risk assessment, - community indicators of health status and risk, - case-control methods for evaluation.

At present, these techniques are gradually winning acceptance as field tools for community diagnosis. Recognition of the importance of social, cultural and behavioural factors in disease transmission has contributed to an increasing involvement of social sciences into health programmes (Manderson and Aaby, 1992a). The integration of these qualitative methods in the epidemiological appraisal, strengthens their relevance and usefulness.

The focus group technique is a particularly interesting rapid assessment method (Khan and Manderson 1992; Kitzinger, 1994). This technique has been successfully applied in the field of compliance with tuberculosis treatment, and has convincingly allowed the exploration of behavioural factors which would otherwise have remained undetected (Lefoooghe et al., 1993).

Anthropological methods have therefore been introduced into rapid assessment procedures in countries where tropical diseases are endemic (Manderson and Aaby, 1992b), reinforcing hereby the value of the epidemiological information collected before the development of a programme.

These rapid epidemiological assessment methods allow field data to be translated into disease control activities (Vlassoff and Tanner, 1992).

4. Epidemiological surveillance

The task of the central, regional and local health authorities is to monitor the epidemiological trends of the main health problems and to take actions; if and when necessary, to adjust the logistics of control programmes to the real needs of the population, and to assess the impact of the control activities. Good planning and management of disease control programmes depend on the availability of reliable, accurate and timely information about the dynamics of a particular disease.

Therefore it is necessary to have an effective information system, that continuously collects, analyses and interprets the registered data, and responds to these informations. Surveillance systems constitute the foundation for adequate health plans (Sandiford et al., 1992).

4.1. Data, registry, notification and collection

4.1.1. Sources and quality of data

While many sources of data are potentially available, the main ones are morbidity and case fatality declared by hospitals, clinics and health centres but also by private practitioners. Aggregate data can be found in official reports, as well as in archives from various levels of government and auxiliary health services. Reports from national laboratories and research centres often contain important information on the occurrence of communicable diseases as well as on their vectors, intermediate hosts and reservoirs. Surveys on specific endemic or epidemic diseases are, as a rule, a more reliable sources of data.

Routine data gathering depends highly on the cooperation of peripheral workers. Experience in many countries has shown that coercive measures, including legal ones, are rarely effective. The voluntary cooperation guarantees better results, even if the participation of peripheral workers is limited in time. The very successful Belgian information system based on the Network of Sentinel general practitioners (Lamotte et al., 1986) and the Network of microbiological laboratories (Walckiers et al., 1991), could well be tried out in Central Africa.

The most difficult and costly component in a surveillance system is the collection of useful data
(Foege et al., 1976). The quality of the data depends on a lot of factors, such as the screening and diagnostic techniques used, the motivation of the staff and of the target population, the logistics of the organized system and the case definition; this has to be standardized and accessible to the lowest technical level. This standardization is not an easy task, as the clinical manifestations of communicable diseases may vary greatly. A good example is the case-detection of Crimean-Congo Virus, which causes serious haemorrhagic fever in Europe (Crimea) and a mild exanthematous fever in tropical Africa. The case-detection can be complicated by the presence of symptomless carriers. Microbiological and parasitic diagnostic methods are time-consuming and often difficult to carry out in the field. Serological methods are of limited diagnostic use due to the delicate balance to reach between sensitivity and specificity. The study of the vectors, their mode of transmission, including transovarian transmission, and their role as reservoir requires specialized methods and staff.

The data have to be representative of the target population. Data collected from health centres and hospitals suffer from selection bias, as their geographical and socio-economical accessibility is limited.

The available information is often unreliable, severely biased, sometimes outdated, and practically unsuitable for decision making. However some data exist at least, and serve for orientational purposes.

4.1.2. Computarized data registration

With an amazing rapidity computers have conquered the developing world. Nowadays nearly every district health officer and control programme manager could have access to computing, if they wished. Computers are still under-utilized in tropical countries by lack of training of the auxiliary staff and of the responsible officers, in techniques of data entry, and in statistical processing. The statistical software is no more an issue, since CDC (Centres for Disease Control, Atlanta, USA) developed and are distributing EPI-INFO, an excellent software programme for data entry, checking, processing, statistical analysis of the data and even wordprocessing to make reports (Dean et al., 1990). EPI-INFO has been made public domain property, and should be made accessible at least to all district medical officers. Another advantage of EPI-INFO is that macros can be written, easily transferred and used without major problems to make regular updates for epidemiological surveillance.

Computarized data entry in survey and even in routine work, can greatly improve the quality of the data, as it allows to spot missing values and outliers. Trials have been undertaken to collect epidemiological data directly on portable computers in the field with very encouraging results (Frerichs and Tas, 1989).

4.1.3. Denominator

One of the major challenges of a surveillance system is to have reliable and updated population estimates. A national census is a good source of population data, but it is very problematic to update it regularly. Essential demographic data are still rare in Africa (Lucas, 1976).

Although seasonal population movements are important sources of the spread of diseases (Prothero, 1987), the population size of the migrants is hardly documented and surely not updated. The difficulty of estimating migrant population size and their morbidity, is well documented in the community diagnosis survey carried out in Gourma-Mali (Chabasse et al., 1983).

To overcome the difficulty of getting reliable population denominators, disease control officers developed special morbidity indices, like the observed incidence rate (OIR) in the case of sleeping sickness (indice de contagiosité nouvelle). The numerator of the observed incidence rate is the number of newly detected trypanosomiasis cases (which is a proxy of disease incidence), while the denominator is the number of examined persons (a proxy of the population at risk). Such a denominator is highly influenced by operational decisions such as to examine the centre of a focus, or at the borders; this would greatly influence the OIR. It has been shown that people's participation is not constant over time, and that there can be large differences in participation among villages and population strata (De Muynck et al., 1990).

To overcome these operational problems some authors propose to use global population estimates such as the estimated incidence rate (EIR) for sleeping sickness (indice de maladie nouvelle, Ricosse et al., 1983). But even such a solution is problematic as many health problems are rare events; by using global population estimates as a denominator, the morbidity rates become so low that they are not sensitive enough to detect important changes in incidence.

The integration of control programmes in the primary health care system produces another kind of denominator problem, as the coverage area of the
health care system rarely coincides with the natural boundaries of disease foci. A solution to these denominator problems is to make the monitoring of the size and the movements of the population under surveillance or at risk, an integral part of the surveillance system.

4.2. Data analysis

Data analysis means to assess the quality of the collected data, to determine the natural history of the disease by discovering trends and their aetiology, but also to detect natural changes in those trends or those due to the control scheme, to determine points at which the disease offers a vulnerability and to evaluate the effects of the interventions on the disease's epidemiology.

The analysis of the collected data allows to verify the quality of the available information, and to estimate the influence of major errors such as missing declarations, mathematical errors, etc. A proper analysis also shows that conclusions can be drawn on temporal and geographical morbidity trends.

4.2.1. Epidemiological mapping

Geographical mapping of the collected data is very important to assess the extent of the spatial distribution of a given health problem. Attention has to be given to the right scale, depending on the size of the area to be covered and on the magnitude of the health problem (Dedet, 1977).

A useful technique is to map on different overlays drawn to the same scale, the data concerning plant ecology, vectors, reservoir animals and the occurrence of a disease. This has the dual advantage of avoiding a single overcrowded map and to enable the observer to easily detect by simple superimposition of overlays, the suggestive correlations among totally different types of data.

A historical example of the value of this approach was given by Italian malarialogists who were able to demonstrate that the Anopheles mosquito was the plausible vector of malaria, by comparing their maps of mosquito distribution with those of the permanent malaria foci (Grassi et al., 1898).

Medical mapping reveals not only the distribution of diseases but also the contours of the risk areas, making it possible to launch appropriate and targeted campaigns of prevention and/or control. For example, it is pointless to carry out systematic vaccination against yellow fever on a global scale, when this disease constitutes a risk only in circumscribed areas.

A great number of epidemiological data vary over time, such as incidence rates, human population figures, range of the movements of vectors and reservoirs organisms; even communication networks and the environment may change over time. Maps reflect the situation only at a given point in time; when situations are unstable, they must be updated at reasonable intervals. Such an update, however, provides an excellent opportunity to improve the quality of the collected data.

Collecting and transferring information to flowcharts or maps is a multidisciplinary exercise that increases awareness of the background of the medical problems. Ideally, a central epidemiology department should have access to all essential data and should receive regular updates, so that epidemiologists can remain informed on new developments and can detect rapidly any worsening of the endemic situation. Such a department should also provide the intermediate personnel and the heads of health zones with relevant maps throwing light on the nosology of the area they cover.

4.2.2. Decentralized data analysis

Data analysis has to be done at all levels of the health care system (Guteff, 1983). A first analysis at the most peripheral level is important for urgent intervention, and to foster the involvement of the local staff in surveillance and control activities. But this implies a minimum level of knowledge and skills of the staff to (though very simple) statistical data processing, analysis and interpretation. In most regions this aspect of the basic as well as the continuous training of health care workers, has been seriously neglected.

4.3 Feedback

The findings of the data analysis have to go to the planners and decision makers, and also to those who have been involved in the data collection.

Diffusion of epidemiological information is a vital element of a proper surveillance, but it can be difficult for many reasons, such as administrative hindrances. A kind of feedback is to forward regularly updated maps of the dominant diseases. These maps demonstrate the permanent concern of control programmes to effectively monitor target diseases. Such updating forces to control regularly the situation, to ask relevant questions and to seek relevant and realistic solutions.

4.4. Use of the information

The available information should be continuously used in the decision making process. Surveillance should not be an isolated activity but be part of the management of control programmes. Unfortunately
due to lack of available data and their poor quality, as well as due to lack of diffusion of the information and shortage of data interpretation skills at local and regional level, the utilization phase is frequently failing.

4.5. Monitoring permanent foci and their extensions

The bio-geography of communicable diseases leads to the even broader field of noso-geography, which is to establish the distribution and delimitation of the various endemic diseases foci, and their potential areas of extension.

Comparing the spatial distribution of communicable diseases with the vegetal ecology in a given area, by means of equally scaled maps, allows one to identify and monitor the limits of permanent disease foci with the vectors' natural habitats, and their extensions.

A focus is a geographically defined area, in which a causal agent (such as *T. b. gambiense*) can be transmitted to susceptible hosts, thanks to ecological and socio-economical factors that favour close contacts between hosts and vectors (Carrie et al., 1980).

A focus consists in three parts:
- a *central active part*, in which the transmission is very difficult to control;
- a *peripheral area*, with rather vague limits;
- and an *extension area*, which is constantly at risk of invasion by the causal agent (Ricosse et al., 1983).

The identification of *disease foci* is important. If the data are collected globally, surveillance of large areas will have to be carried out with the same methods as in the centre of the focus, which in fact might need a more intensive approach.

By analysing correlations between physico-chemical characteristics of geo-morphological layers on the one hand and the extension area of a specific disease on the other, it is possible to highlight areas where vector densities may rise high enough for the focus to become permanent. For example, in the case of plague in Central Africa, the type of land determines whether the density of the rat reservoir will become high enough to constitute a real human health hazard; in the case of schistosomiasis the type of bedrock on which the surface water stands will largely determine whether a suitable environment is provided for the vector snails. The relationships between specific plant communities and invertebrate vectors are similarly relevant.

5. Evaluation

There are several methods to assess health programmes and services. They include the evaluation of the relevance of the actions undertaken to modify the baseline situation, of the input (such as drugs, traps, insecticides, etc.), of the process itself (vaccination sessions, diagnosis and treatment), of the outputs (measured by immunization rates, coverage rates, etc.) and of the biological impact (such as reducing the incidence and/or the lethality of, for example, sleeping sickness).

Evaluation is a multidisciplinary activity, of extreme importance for the care and the cure of the people. Hopkins (1993) considers it the *alpha and omega* of intervention and prevention strategies. For a preventive, curative and/or vector control intervention to be effective, the care system has to be functional: the necessary inputs have to be made, the staff has to be trained and motivated, the target population has to participate in sufficient numbers, the programme has to be well managed, and the activities have to be of acceptable technical and human quality.

For some public health managers the evaluation has to focus nearly exclusively on the performance of the health services, rather than on its biological impact (Unger and Dujardin, 1992; Akerman and Nadanovsky, 1992). Although assessments of the process are indispensable, they provide only a partial answer to the real question of how to reduce the suffering of the target population due to a particular health problem. The answer to that question can be obtained through indicators such as incidences, risks, mortality, quality of life, etc. This implies quantifiable objectives, reliable baseline data, constant monitoring of activities, and intensive surveillance of the health of the target population.

Evaluation further implies to answer the question of what the health status of the target population would have been, had the particular control activities not taken place. For this reason a control area outside the scheme is needed, although parts of the programme area can be used as internal controls (Unger 1985).

In the field there is a need for simple and efficient rapid assessment techniques, such as the *tracer methodology*. This means to use a limited number of diseases or parameters to monitor the evolution of the health situation. This method has been successfully used to assess rural health services in Ghana, based on the tracer conditions of cough, diarrhoea and fever (Amonoo-Lartson and De Vries, 1981).
Evaluation of health and health care is an approach, in which epidemiologists are specially able to participate and are essential, although other specialists have also to come in. Yet in many developing countries there are nearly no epidemiologists involved in health evaluation tasks (Waters, 1979). Therefore training of indigenous epidemiologists without medical qualification has to be promoted, while sufficient attention to the structure of their career must be given.

6. Epidemiological modelling

In 1980 Stallones has put forward as central axiom of epidemiology “Disease does not distribute randomly in human populations”. Variations in the incidence and spread of tropical diseases depend upon the dynamic interaction of a multitude of biological, ecological, demographic, socio-political and behavioural factors. This great complexity makes it difficult to arrive at a quantitative understanding of the epidemiology of tropical diseases without the help of special tools such as epidemiological models (Remme, 1992).

An epidemiological model represents a dynamic system of strictly interrelated epidemiological factors able to mirror real life (Cvjetanovic et al., 1978); it is a simplification of a complex reality, as it removes confusing unimportant factors and allows the investigator to concentrate on major trends without information overload (Habtemariam, 1989). Modellers have to select the main epidemiological factors, the choice of which has to be guided by a conceptual framework (Palloni, 1987). The causal model provides such a framework, examples of which can be found for sleeping sickness (Habtemariam, 1989; De Muynck et al., 1992) and for Chagas’ disease (De Muynck and Levêque, 1992).

In the early days of mathematical modelling, the emphasis was on parsimony; the resulting models were viewed as mere academic exercises, and lacked operational relevance; consequently they did not generate the users’ confidence (Gettinby, 1989). Field applications of mathematical models, such as the one of malaria eradication by MacDonald (1957), frequently produced results that were at great variance with the model predictions, due to deficiencies in the model and inadequate specification of the parameters (Najera, 1974). Today the aim of epidemiological modellers is to provide workable tools for epidemiologists and public health administrators. The computer evolution has largely contributed to the shift from purely mathematical models to simulation models which can handle an endless number of variables and interactions (Habbema, 1992); they can thus contribute much better to predict epidemiological trends. Therefore the epidemiologists and public health administrators find the modelling so useful for planning, monitoring and evaluation of tropical disease control programmes.

In infectious diseases epidemiology mathematical models contribute in two purposes:

a) a better knowledge of the biological cycle of parasites; these models were called by Rochet (1991) hypothesis generating and mechanisms elucidating models; b) to predict the natural history of a disease, and to assess the impact of man-made intervention models. These are decision making models, having potentially a big impact in disease control programmes (Bailey 1975).

The advantages of epidemiological modelling are numerous, as mentioned by Remme (1992):

- they make the epidemiological approach comprehensive. Classical epidemiological field research tends to address a limited number of issues at a time; while disease control needs a more global approach. Through modelling a large set of alternative approaches can be examined easily, efficiently and within a short period of time, as was shown by Habtemariam (1989) in his model of animal trypanosome control;
- they allow an integrated analysis and synthesis of knowledge and information, such as for example the estimation of the lifespan of *O. volvulus*, which was a crucial factor in the planning of the duration of the Onchocerciasis (OCP) Control Programme (Plaisier et al., 1991);
- they enable a prospective evaluation of control programmes, which is the most valuable application of modelling by allowing rational choices of control strategies, such as the continuation of vector control in the OCP programme (Remme et al., 1990); and long-term actions in the case of leprosy control (Lechat 1971);
- they allow an appreciation of the uncertainty in the estimates through sensitivity analysis. The latter studies the robustness of the conclusions, when the numerical values of the parameters are modified in the model. An example is given in the trypanosomiasis model developed by Shaw (1989): in this model she studied the impact on the cost per unit of benefit when the epidemiological and operational assumptions are changed; her work showed that case finding and treatment is more cost-effective than vector control at low incidences of sleeping sickness.
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Hereby sensitivity analysis allows the study of uncertainty as detailed epidemiological models involve a lot of parameters, of which many cannot be estimated accurately; this permits to put confidence boundaries on the predictions of the model.

- they contribute to a rational planning of control and evaluation activities; usually the control of infectious diseases is based on a weighted combination of strategic elements such as case-finding, treatment and vector control in sleeping sickness. Through modelling a rational balance can be obtained between the different elements, as well as at the start as during the implementation of a control programme. As we are trying to eradicate certain diseases such as poliomyelitis and guinea worm, we will have to address a number of epidemiological questions for which empirical data are still lacking; modelling helps to elucidate these problems (Thacker and Miller, 1991).

- they allow to predict natural epidemiological trends of the incidences, under a given programme and after the cessation of an active scheme; this is of paramount importance for the management of control programme and for donor commitment. The occurrence of some 4,000,000 people dually infected by HIV and Koch bacilli, exemplifies the need to predict the future trends of the prevalence for pulmonary and extra-pulmonary tuberculosis, and of the incidence for Tb and AIDS infections (De Cock et al., 1992).

- the development of a model brings together scientists of different disciplines to communicate on an equal and complementary level, which is a condition sine qua non for any collaborative work, but specially for epidemiological programmes; and stimulates the development of a common language (De Muynck et al., 1992).

There are of course a number of problems related to epidemiological modelling, such as the danger of oversimplification, the excessive emphasis on mathematics and informatics, and the lack of transparency which can hide connections between factors that can be observed in real situations.

It should also not be forgotten that models are only as good as the data they rely on. However, at present modelling has come to the point of being more than a purely intellectual exercise. Nowadays it has practical implications and could be a daily working tool for anyone involved in the epidemiological study and control of diseases of public health importance.

7. Clinical epidemiology

It is well known that careful clinical observation and keeping on the watch for clusters of exceptional events are at the basis of epidemiological discoveries. The clinician who had observed four fatal cases of liver angiosarcoma in the space of a few months, and who had made enquiries about exceptional exposures, was the foundation for the discovery of the causal association between occupational exposure to vinyl chloride and liver angiosarcoma (Creek et al., 1974). The careful epidemiological studies carried out afterwards confirmed the suspected association and quantified the dosis response relationships (Monson and Peters, 1974). Similarly, Acheson (1979) has pointed out that on 19 proven carcinogenic factors for man, 13 were first brought to attention by an alert clinician who had observed a cluster of cases.

More recently the careful observation of the first three cases of AIDS in Belgium was at the basis of the hypothesis of the heterosexual transmission (Taelman et al., 1983), and of the first case control study on this topic in central Africa (Piot et al., 1984).

Although these examples demonstrate the important contributions that clinicians can make to epidemiology, this is not what is meant by clinical epidemiology. According to Sackett (1969) clinical epidemiology is "the application by a physician who provides direct patient care, of epidemiologic methods to the study of diagnostic and therapeutic processes in order to effect and improve health". Clinical epidemiology helps to connect hospital clinicians with office bound public health epidemiologists; hereby it accelerates the development of effective and efficient health care (Sackett, 1983).

The focus of attention of clinical epidemiologists is the design and analysis of clinical trials, the natural history of diseases, the development of screening, diagnostic, therapeutic and follow-up criteria, the establishment of ranges of normality and the development of strategies to warrant quality in the acquisition of clinical information from patients (Feinstein, 1972).

Clinical epidemiology provides to clinicians the intellectual tools to disclose not only the natural history of disorders presented by their patients, but also the natural history of medical care and its outcome (White, 1974). This way of thinking allows the clinician to develop a more balanced perspective for the natural history of a given health problem than can
usually be obtained from personal experience (Acheson, 1979); it gives the clinicians a population perspective on the care of individual patients, and a scientific basis for preventive measures (Fletcher, 1992).

In Third World countries clinical epidemiology contributes to the promotion of the control of infectious diseases and to community epidemiological research (Morrow and Buck, 1983). In developing areas the gap between the size of the health problems and the available control measures is so much larger than in technically advanced countries, that the clinicians are compelled to base their decisions upon epidemiological principles. As nearly everything that can be done for a patient has a cost attached to it, ideally no diagnostic, therapeutic or preventive measure should be undertaken unless the expected benefits exceed the expected costs (Weiss, 1986).

This supposes that the outcome of a given health measure is predictable. However, there is a great amount of uncertainty on the immediate and longterm effects of most decisions taken in the health settings. Clinical epidemiology studies allow to gather the necessary data to support decision-making in the context of uncertainty.

Pharmaco-epidemiology is a branch of clinical epidemiology, with particular relevance to public health in developing countries (Guess et al., 1991). Its role in the assessment of the safety and the effectiveness of medical interventions can be made clear by the example of Oral Rehydration to treat diarrhoea or of Fansidar to prevent chloroquine-resistant falciparum malaria.

Clinical epidemiology has a very important contribution to make to the education of the health professionals, and should be taught in all medical schools, especially in those of the Third World countries.

8. Epidemiological training

Today the usefulness of epidemiology to plan and manage health programmes and services is generally accepted, and students and professionals are aware of the need for epidemiological training. But this has not always been the case. In a survey carried out in 1975 in the UK, last-year medical students assessed the courses of biostatistics and epidemiology to be of limited usefulness (Donnan, 1976). Similar observations were made in USA (Colton, 1975), and even the academic staff was not always convinced that epidemiology and biostatistics should be part of a medical curriculum (Acheson, 1973).

That lack of recognition for epidemiology has its origins on the one hand in the poor interest of the clinicians in quantitative appraisal (Cassells et al., 1978; Weiss and Samet, 1980), and on the other hand in the inefficiency of the epidemiological training itself (Sackett, 1969).

In the seventies a novel approach became necessary for epidemiological training (Warren and Acheson, 1973). The creation of new medical departments was the starting point of new approaches to modern epidemiological training: at Belfast epidemiological work was incorporated in the practical training of family practitioners (Pemberton, 1973), and in Canada, McMasters University fully integrated clinical and epidemiological training (Leeder and Sackett, 1976). Also at Leicester a novel approach was tried out (Clarke et al., 1980).

In English-speaking and French-speaking Africa various short epidemiological training programmes were started, and relied heavily on fieldwork; a standard curriculum was developed under the guidance of WHO (Lwanga and Tye, 1986).

One of the problems that had to be tackled was how to incorporate biostatistics in the medical curriculum. Novel approaches were tried out. A promising one is the combination of biostatistics and epidemiology in a single EPISAT course, in which the part on biostatistics puts emphasis on the acquisition of skills to describe and analyse field data as a basis for decision-making in community diagnosis, surveillance and evaluation, rather than on formulae and methods alone (Rimm, 1985; De Muyck, 1986). This integration in a joint EPISAT course is still exceptional (Clarke et al., 1980; Peters, 1990).

Another promising approach is the use of the computer as a teaching tool. Computer Aided Teaching (CAT) has a lot of advantages; it is very well appreciated by the students and allows individual and repetitive monitoring throughout the whole course. In the field of epidemiology a basic computer aided self-teaching course, called EPITROP, has been developed (De Muyck et al., 1987). Its teaching potential was assessed in a controlled pedagogical trial, and was found to be similar to classroom teaching (Liefgooghe et al., 1991). Similarly computerized learning games have been developed, a first one was the San Serriffe game (Macfarlane and Moody, 1982).
Assessment of physicians' training in epidemiology and biostatistics has shown that their residual knowledge is quite low, and even insufficient to understand correctly the medical literature (Wulff et al., 1987; De Muynck and Van Loon, 1991). This brings us to the problem of the relevance of epidemiological training. At present such training is still too much oriented towards transfer of knowledge, rather than to delivering the necessary skills to analyse situations, to support decision-making and to solve problems. Epidemiological training should be part of an overall plan of continuous upgrading of epidemiological skills by regular supervision of the alumni when they take up their field responsibilities.

9. Conclusions

Epidemiology is concerned with the health of populations, and is not limited to vector-borne diseases, but it covers the whole range of acute and chronic disorders, and even health care utilization. It must thus monitor not only malaria, sleeping sickness, tuberculosis, leprosy, brucellosis, and bacterial or viral meningitis, but also hypertension, congenital metabolic disorders, pollution and its health risks and also cancer with its links with presumed carcinogens (tobacco, heavy metals, various types of radiation, etc.): in fact the whole range of events and factors that may influence human health.

The contribution of epidemiology to control priority health problems starts with a community diagnosis. Various disciplines are involved, such as clinical medicine, entomology, physiology, anatomo-pathology, psychology, sociology, and anthropology. The study designs to collect data for community diagnosis may be descriptive, analytical, ecological, or even experimental. The classical indices such as mortality and morbidity are no longer sufficient and new ones related to positive health, to quality of life, and to equity must be developed. To really contribute to the planning of control programmes and health services, the community diagnosis has to be valid and timely. To ensure opportune information, rapid assessment methods have been introduced in the epidemiological toolbox.

Health surveillance systems constitute the foundation for pertinent health programmes, but nearly everywhere in Africa the national health information systems have serious structural and functional problems. Excessive centralization, lack of supervision and feedback mechanisms are key issues. The introduction of sentinel surveillance and computers at the level of the health district has to be encouraged, and could considerably improve the quality of the information produced by the surveillance system, while trying to regularly update the population denominators. At local and district levels use of maps is recommended. Disease surveillance must not only monitor health districts, but watch particularly the active and potential foci of transmission.

Epidemiologists have to be involved in the assessment of health programmes. The epidemiological evaluation must not be limited to the implementation of programme activities, but should also address the issues of epidemiological impact of efficiency and also of equity. To plan sustainable programmes epidemiological considerations must be taken into account.

Mathematical models are of increasing importance to epidemiologists to simulate events that cannot be measured easily, such as the impact of an intervention or the effects of ecological modifications before the intervention takes place. Unfortunately mathematical modelling is still a kind of academic exercise, with limited operational relevance. Models have to become a tool for planning and management of disease control programmes.

The input of epidemiology in patient care has become so important in recent times, that a new name has been given to it: clinical epidemiology. This branch of epidemiology brings together curative care and community health practice. It can help to develop more scientific and quantitative means to assess the clinical practice of medicine and its advancements. In the tropics it can make important contributions to upgrade the status of the epidemiological discipline and of epidemiologists. Clinical epidemiology should be an integral part of the training of all curative health workers in the developing countries.

Teaching and practice in epidemiology have been the continuous concern of all those who want to train competent practitioners, as is demonstrated by the number of reports on the subject, by the attempts to organize special training sessions, and by the development of special computer-assisted training tools. Unfortunately public authorities pay scant attention to the training of such specialists and provide no interesting career opportunities for them. This is an additional reason to encourage promising and carefully selected candidates despite any difficulties involved, to step forward on their own initiative, to be selected...
carefully and be well trained. This is not going to succeed unless the recruitment of motivated candidates, who have received thorough academic and practical training, is given the priority it deserves. Clear-thinking epidemiologists who are both dedicated fieldworkers and imaginative thinkers are essential to explore operational, effective and efficient ways to improve human health.

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