

MEDICAL ECOLOGY¹CHARLES M. VAUGHN²

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Ecology involves the study of the interactions of organisms with each other and their physical environment. An ecosystem is a unit consisting of the biotic communities and the nonliving (abiotic) environment that interact to produce a stable system. Such a system is in a dynamic equilibrium which involves change to reach stability. Communities represent populations of organisms and their interrelationships with each other and their environment. Parasitology is a specialized branch of biology that deals with specific organisms and their interactions which result in disease entities. Since the time of World War II (WW II) growth in knowledge has strengthened the newer disciplines of virology, clinical mycology and medical entomology and has greatly expanded the content areas of parasitology and bacteriology. In the 1940's social medicine in England was identified as being comparable in scope to the area of knowledge termed medical ecology in Canada and the United States (LeRiche and Milner 1971). Medical ecology may be defined as the study of

all diseases in groups of people in relation to both their biotic and abiotic environments.

At the time of our entry into WW II, and its global ramifications, a small number of Americans were actively practicing parasitologists or were in training in this area. Many were called into the Army and Navy to serve in this capacity along with entomologists and a small number of physicians with specialty training in tropical medicine. Many physicians were trained rapidly at the Navy Medical School and Walter Reed Army Hospital in intensive courses in tropical medicine. As a new arrival at Walter Reed, I found men with ten to fifteen years experience as practicing parasitologists placed in the same group as the newly inducted graduate students. In comparing my physician roommate's text material with my own material from the parasitology course I had been assisting in at the University of Wisconsin, I found, much to my surprise, that my prior training had a greater depth than his current studies. Unfortunately, practically none of this subject matter was included in medical school curricula at that time, with notable exceptions being Harvard, Johns Hopkins, North Carolina, Louisiana State and Tulane. It is interesting to note that Schools of Public Health played important roles in these institutions.

Following WW II, a major influx of returning veterans with overseas experience in medical ecology moved into colleges, universities and schools of medicine and the subject matter was incorporated widely into curricula. The United States became globally involved following WW II and had an ever increasing role in activities involving our citizens all over the world in a variety of endeavors.

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This role and its responsibilities required a strong base of training in the health professions to meet the problems of human disease caused by animal disease entities. Alas, such was not the case. A recent survey, a little over three years ago, showed that 70% of American medical schools devoted less than 16 hours to teaching tropical medicine to their students (Schultz 1977). A similar reduction in parasitology offerings in colleges and universities has occurred with the retirement of senior faculty and replacement of these offerings with newer disciplines.

LeRiche (1967) recently summarized estimates by Stoll (1947) and the World Health Organization sources on selected worldwide disease prevalence so that all living persons could have an infection if they were evenly distributed (see table 1).

TABLE 1
World Wide Disease Prevalence.

Disease category	No. human infestations or infections
Helminth	3.5 billion
Hookworm	700 million
Schistosomiasis	200 million
Onchocerciasis	40 million
Malaria	25 million
Leprosy	10 million

Of the approximately 60 million total annual worldwide deaths from all causes, 30 million are in children under the age of 5. Half of these deaths, 15 million, are attributed to the malnutrition-intestinal infection combination (Howard 1971).

Pollack (1968) stated the caloric energy wasted as a consequence of infections and fevers which increase body metabolism and cause nutritional imbalance through accelerated caloric and protein use. Heat production of the human body increases about 13% for each °C or about 7.2% for each °F rise. A single acute febrile episode of malaria requires an average energy demand of approximately 5000 kilocalories per day in the adult—an energy demand which is equivalent to two days of hard manual labor. He extrapolated that, in a population with a 2,200

calorie average diet, if 33% had a febrile episode, up to 90% had a worm burden, and 8% had tuberculosis, this would create an energy demand equivalent to 7500 tons of rice per month per million people over and above normal requirements. This represents a waste of 25% to 30% of the total energy yield from annual grain production in many agricultural societies. Pollack concluded that individuals on subsistence diets can be driven into malnutrition by the additive demand of disease or parasites, and that during episodes of fever, protein balance cannot be maintained regardless of the quality or availability of the diet.

Some further data will help to identify the present problem in medical ecology. In 1976, the United States allocated \$800 million for cancer research, yet only \$40 million were expended during that same time by all nations for research on tropical diseases (Schultz 1977).

Stoll (1947) stated that we have noted just over 2251.7 million heminthic (worm) infections assigned to 2166.8 million people on the planet. If you have gained the impression that it must be scientifically labelled a "tentative statement", you may also have gained the impression that it was arrived at lightly. Both impressions are correct. Later Stoll stated that the world population, according to informed predictions may reach 3300 million by the end of the century, an increase of 50%. The parasitoses, by extrapolation, may grow even more, for some of the areas marked for most population growth are among those with higher helminthic indices. Sawitz (1956) expanded Stoll's (1947) information to include the protozoan parasites of man. Warren (1974) updated Stoll's (1947) estimates for the United States to include 4 million persons infected with *Ascaris*, 2.2 million with *Trichuris*, 42 million with pinworm, 700,000 with hookworm and 400,000 with *Strongyloides*. Except for hookworm, these estimates represent increases over Stoll's (1947) estimates, but may mark a slight decrease in prevalence when the population increase is considered.

The World Health Organization estimates for 1977 indicate 348 million people in North America and 4,045 million

people in the world (Warner 1978, van den Heuvel 1978). With these population increases, major increases in intestinal worm parasites were noted. *Ascaris lumbricoides*, the large roundworm, infects 1 in 4 persons worldwide, for a total of at least 800 million. Estimated glycogen consumption in 1 year of all ascarids in people of China equals the carbohydrate value of 143,000 tons of rice (Noble and Noble 1976). Between 726 and 907 million people suffer from hookworm infection. Whip worms (*Trichuris trichiura*) infect 350 million.

Hiatt (1977) noted that the World Health Organization has mounted long range programs against six tropical diseases that contribute greatly to poverty, chronic sickness, and death in most of the developing world. The diseases include malaria, schistosomiasis, river blindness, trypanosomiasis causing sleeping sickness and Chagas' disease, leishmaniasis and leprosy (Hansen's disease). This paper will be limited to a discussion of schistosomiasis, hookworm, blinding filaria and blood inhabiting protozoa.

Schistosomiasis or bilharziasis (blood flukes) infects over half the Egyptian population and worldwide over 200 million people (approximately the present total U.S. population) are infected in some 70 countries in Africa, Asia, South America and the Caribbean (Schultz 1977). Schistosomiasis is now ranked at least second to malaria in importance as a parasitic disease throughout the world, (Wright 1972). The disease has been identified in mummies found in tombs dated about 1200 B.C. (Schmidt and Roberts 1977). In Moslem countries, which comprise most of the endemic regions for two species, the religious requirement of urination, defecation and abluion before praying or eating is a great source of infection.

Dam construction in Africa has created new increased areas of risk. Schistosomiasis is increasing in prevalence as man attempts to use water and land resources more efficiently (Mahmoud 1977). The development of many countries in Africa and South America depends on the construction of new dams and the initiation of irrigation projects, which provide ideal breeding places for the snail hosts of the

parasites. Thus the disease is a challenge not only for physicians and scientists but also for water engineers, economists and politicians. A \$10 million irrigation project in southern Rhodesia had to be abandoned 10 years after it was started because of schistosomiasis, (Osmundsen 1965). The Aswan Dam restricts wide fluctuations in the water level of the Nile making it possible for the production of four crops per year (Van der Schalie 1974). Perennial irrigation practices in the Nile preceded the Aswan Dam construction and the prevalence of schistosomiasis was about 60% in the Nile delta area. In the valley between Cairo and Aswan, the river was subjected to annual flooding and only 5% of the population were infected. Four years after completion of the dam the prevalence of the urinary blood fluke infections ranged from 19% to 75%, with an average of 35%, a seven fold increase. In the area above the dam, infection was low prior to construction. In 1972, 76% of the fishermen examined in the impounded area were infected. In Northern Nigeria the infected population around the lake created by the Kainji Dam has doubled in three years (Schultz 1977).

A specific study of a newly identified focus of *Schistosoma mansoni* in the Dominican Republic (Olivier *et al* 1952) noted a restricted distribution of the snail host *Biomphalaria (Australorbis) glabratus* in the streams adjacent to the town of Hato Mayor. A serious endemic focus existed there and the disease was being acquired by a relatively large proportion of the children in the town. Because of the narrow geographic limits of the focus, it was well-suited for a mollusciciding operation for control of *Schistosoma mansoni*. A successful mollusciciding operation resulted in the destruction of the snail host (*B. glabratus*) by using sodium pentachlorophenate (NaPCP) (Santobrite) in briquette form (Vaughn *et al* 1954). A single application of NaPCP at an estimated rate of 15 ppm eradicated the snail host from the arroyo Paña Paña for a 6 month interval. Several methods of briquette application were used and evaluated by colorimetric tests of water samples.

Wherever irrigation projects are de-

veloped, this disease has spread to regions where it did not previously exist, such as the semi-arid Arabian peninsula. A new potential danger exists in the area above the projected Itapu dam being built on the Parana River by Brazil and Paraguay. The earthen dam will be higher than the Aswan Dam. The delta area to be impounded is already a major area of both schistosomiasis and malaria. The impoundment will greatly increase the potential breeding areas for the intermediate hosts of both diseases.

Stoll (1962) estimated 620 million people were infected by hookworm disease with an estimated *daily* blood loss equal to the total blood volume of 1.5 million people. A current World Health Organization (WHO) estimate (1977) indicates that between 726 and 907 million persons are infected. Consider the food energy involved in this daily loss with no benefit to humanity. The big three C's of the tropical economy are cane, cacao and coffee.

Carr *et al* (1954) conducted an extensive hookworm eradication program utilizing health education, preliminary screening examinations, clinical treatment, and sanitation improvements. Treatment was difficult in severe hookworm disease in patients weakened by the anemia resulting from the infection. In such severe cases patients had perhaps 2.0 gm or even 1.5 gm of hemoglobin/100 cc of blood. (Normal hemoglobin content of the blood ranges from 12 gm/100 cc to 16 gm/100 cc.)

Another round worm group of major importance are the filarial worms which involve humans, mosquitoes and/or flies. Filariasis infections are presently estimated at about the 250 million level worldwide mainly in Africa, India, Southeast Asia, China, Phillipines, Pacific Islands, Central and South America. *Microfilaria* in blood exhibit both nocturnal and diurnal behavior associated with the feeding habits of vector mosquito species. Adult worms in the lymphatic system block the lymph vessels and glands often leading to elephantiasis of appendages and external genitalia. A *Cincinnati Enquirer* headline which appeared in October 1977 was taken from the Mossi tribe proverb in Upper Volta:

The rivers are eating the eyes. Onchocerciasis, commonly referred to as river blindness has caused the abandonment of much African farmland and, in some villages, to blindness in half the remaining adult males (Hiatt 1977). In the 420,000 square mile Volta River basin composed of savannah land in parts of the West Africa states Dahomey, Ghana, Ivory Coast, Mali, Niger, Togo and Upper Volta, there were over a million sufferers and 60,000 are blind and many more have impaired vision. WHO has embarked on a 20 year program (\$120 million), now in its fourth year, against the fly that blinds (Connor 1978). Worldwide it is estimated that between $\frac{1}{4}$ and $\frac{1}{2}$ million are blind in an infected population of 40 million. Incidence of blindness was estimated at 85% in Africa and 30% in Central America.

Recently this disease has newly discovered foci in widely separated areas including Brazil, Columbia, Venezuela and Yemen Arab Republic. As the long range programs to promote study and control expand, more foci of this infection are found. Geographic variations in the disease are caused by different strains of the nematode parasite and different species and strains of Simuliidae (black flies). In their continuing adaptation to each other in these varied geographic areas the parasites and insects have evolved different habits and particularly vary in their ability to damage different target organs (Connor 1978). Total programs require treatment of patients and of whole communities to reduce the reservoir of microfilaria and elimination of the black fly. Success of this type of program occurred in Kenya with the complete elimination of black fly *Simulium neavei* breeding foci. The topography of Guatemala precludes elimination of the black fly, so that nodulectomy of all detectable nodules by skilled teams is the major program. It has reduced the intensity of infection and the severity of eye disease but recent data reveal that prevalence remains unchanged.

One fourth of the world's population presently lives in areas where malaria is transmitted and 1,163 million people live at risk. Malaria has been the subject of

the largest global disease eradication program in the world, begun by WHO in 1956. The program has proven to be successful. Thanks to the combination of DDT spraying, improvements in living conditions, and water-control measures, approximately 7,000 million people who were once at risk for malaria are now free of the danger of exposure (Schultz 1977). Following the initial successes, unforeseen problems have arisen: resistance of malaria-carrying mosquitoes to insecticides, of parasites to drugs, of man to the intrusion of malaria-control workers into his houses and radical changes in the world's economy (Peters 1977). Despite the initial successes, WHO reports that malaria still exists in 104 countries and in at least two countries, India and Sri Lanka, where malaria transmission had been under control, the disease is now resurgent. In the India subcontinent, the situation today is a calamity and threatens to get worse unless there is a rapid mobilization, nationally and internationally of malaria-control services (Peters 1977). Data from the Director of the India National Malaria Control Programme indicates 100 million cases in 1952, negligible cases in early 1960's, about 100,000 in 1965, 500,000 cases in 1970, 1.1 million in '71, over 3 million in '74, 5.2 million in '75 and 4.7 million by end of October 1976.

In British Guiana there was a high incidence of malaria along the heavily populated coastal areas prior to the 1946-50 campaign to eradicate *Anopheles darlingi*. As a result, large portions of these areas were developed for housing, industry and other uses that displaced much of the livestock population formerly there. In recent years these man-made imbalances altered the environment to such an extent that another species, *A. aquasalis*, previously a livestock feeder, now used the new source of food, namely humans. Outbreaks of malaria after 16 years are now transmitted by a vector previously harmless to man. Due to the altered environment, this species was forced to change its feeding habits and a new public health problem is present (Giglioli 1963).

The present failure of insecticides against mosquitoes, of drugs against para-

sites, and socioeconomic changes point up the current dilemma of malaria control or eradication. The U.S. Army chemotherapeutic screening program, continued after the pharmaceutical industry opted out of the antimalarial program, has brought forth at least one new anti-malarial drug, now in field trials. Some basic research beckons toward a malarial vaccine some distance in the future. The WHO Special Program for Research and Training in Tropical Diseases may have funding available for basic research and training of new workers in this area (Peters 1977).

African sleeping sickness is endemic in a vast expanse of the savannah or grassland area of Africa, where at least 35 million people live at risk from the trypanosomes and tse tse flies. It is estimated that at least 10,000 new cases occur annually (WHO). Recent reports of Americans contracting the disease indicate fatalities in cases after arrival in U.S., treatment and recovery when hospitalized en route home (in France). Closer to home a similar situation occurs in Chagas' disease with 10 million infected and 35 million at risk in Central and South America. This disease like, all those discussed earlier, is a disease of the poor. The reduviid bugs live in the walls, floors and roofs of the primitive mud/cane or corn stalk houses. Children sleeping, 2 to 4 in beds, close to the walls suffer 8 to 10 new bites per night. In the first decade of life, excessive infections result in major damage to musculature, especially heart muscle (myocardium), by intracellular stages, termed leishmania bodies. Fatalities due to this infection have decimated entire villages in Latin America.

Leishmaniasis is a wide ranging group of disease entities all of which are intracellular parasites of human tissues as leishmania bodies or amastigotes. Visceral leishmaniasis, termed kala azar, extends from the Middle East throughout Asia especially in the Indian Subcontinent. In much of the same area of the Middle East, Africa and Asia Minor, a cutaneous leishmaniasis or oriental sore is present as moist or dry surface sores. In the western hemisphere a mucocutaneous form of the infection variously is

benign (uta), affects the pinna of the ear (chiclero ulcer), or the mucocutaneous area of the nasal septum and palate (espundia). The first two described forms of this disease are also reported in the western hemisphere. No accurate numbers are available for this complex of identical morphological strains with widely differing physiopathological effects on mankind.

Every parasitic disease known to man has been diagnosed recently in the United States. Some are transmitted here, including giardiasis, trichinosis, toxoplasmosis and amebiasis. Others, like malaria, African trypanosomes and schistosomiasis, are imported. Each year at least 100 cases of *P. falciparum* are diagnosed in the United States. The case fatality ratio in patients admitted to civilian hospitals is 24 times greater than in patients admitted to military hospitals. As noted earlier, Americans ill with African sleeping sickness fared better in Paris hospitals than those hospitalized in the U.S.

Missed diagnosis is a major problem in the management of patients with parasitic diseases in the United States. The medical profession could become more interested in several ways because tropical medicine represents a major area for biomedical research: control, vaccines, drugs affecting metabolic pathways, immune responses, biological controls.

These diseases afflict the illiterate and indigent peoples in remote regions of the world who have little or no influence in the councils of government and public health (Connor 1978).

At present, when the basic biology of a parasite causing human disease is studied it must be attacked on all fronts, from the molecular-biochemical level to field studies including population genetics, ethology and interactions of all involved organisms and their physical environments. Put briefly, herein lies the challenge today in medical ecology to solve the forgotten problems of forgotten people far from the United States.

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