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HENRY VAN DER SCHALIE

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INTEREST in the relatively new field of medical malacology was aroused especially during the last war when a number of American soldiers contracted Oriental blood fluke (*Schistosoma japonicum*) during General MacArthur's campaign in Leyte. The need for studying the mollusk intermediate hosts of a number of snail-borne diseases then began to receive somewhat the attention accorded insects involved in vector roles in the sister field of medical entomology. While the process of obtaining support has been slow, more and more basic studies are being initiated to understand better the roles of snails in relation to human and domestic animal diseases. This study is one with many fascinating aspects; it also presents challenging problems, which are far-reaching in the manner in which they concern human health, economics, and the general welfare of many rural communities. While it would be interesting and quite impressive to show some of the intricate interrelations among fields, using schistosomiasis (human blood fluke disease) as an example, it will be just as worth while to consider here another snail-borne disease affecting humans, fasciolopsiasis. Included would be a review of the life cycle of the worm parasite in its relation to its snail host, the role of the snail host in limiting the range of disease infestation, the immediate need for better knowledge of the natural history of the snail hosts, and a brief consideration of some of the difficulties experienced in training personnel to assist in alleviating suffering brought about by this or similar diseases.

MY INTRODUCTION to the problems involved in the control of the giant human intestinal fluke that causes the disease known as fasciolopsiasis came in 1929, while I was a graduate student at the University Biological Station near Cheboygan. Dr. Claude Barlow spent that summer at the station; he had recently returned from China, where for many years he had studied this disease and had just completed a very careful and scholarly dissertation on the life history of this human intestinal fluke. It was an especially noteworthy occasion to me, because he kindly gave me a few of the worms recovered from his own intestinal tract. While working in China, he had infected himself in order to have a ready supply of material for his studies and to understand better, as a medical doctor, the symptoms and problems brought on by the disease in the patients that same to the Shaohsing Christian Hospital, where he worked. His appraisal of the reaction of a human to this disease will be referred to later.

It should be mentioned that, following this assignment in China, he went to Egypt, where he studied another serious human snail-borne disease, schistosomiasis; there he again infected himself with that blood fluke.

HENRY VAN DER SCHALIE's studies of the snails which carry disease-causing parasites have made him an authority on this subject, frequently called to trouble spots, such as those mentioned in this article, and a member of the Commission on Parasitic Diseases of the Armed Forces. Dr. van der Schalie is a graduate of Calvin College (A.B. '29) with higher degrees from Michigan (M.S. '31, Ph.D. '34). In 1938 he became a member of the faculty as Assistant Curator of Mollusks in the Museum of Zoology and Instructor in Zoology, College of Literature, Science, and the Arts. He was made Curator and Assistant Professor in 1944 and was advanced to a full professorship in 1957.

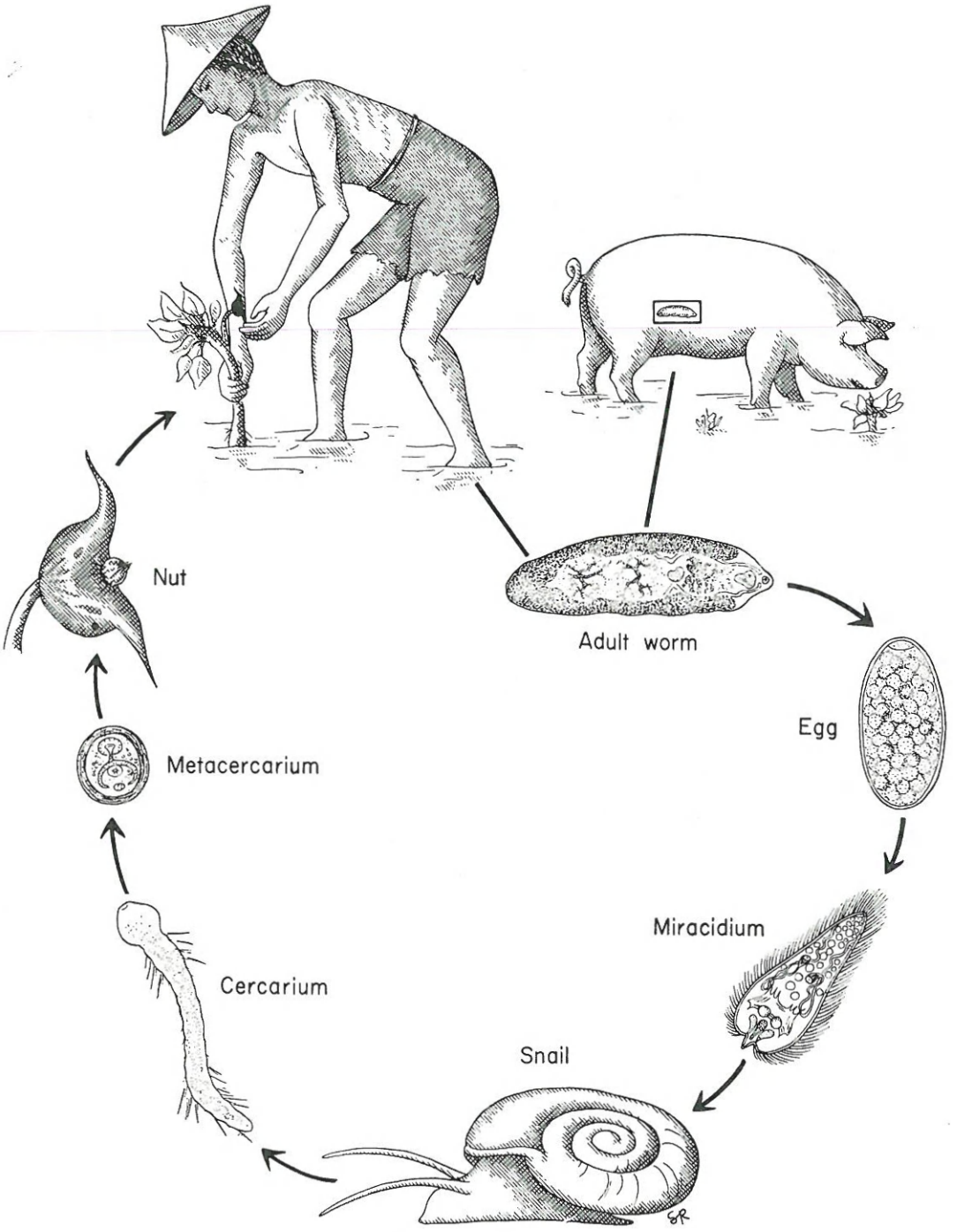


FIG. 1. LIFE HISTORY OF *Fasciolopsis Buski*

Fasciolopsis buski, *the Large Intestinal Fluke, is the agent for fasciolopsiasis in Kwantung and Chekiang provinces of China and in Formosa, Annam, Tonkin, Pakistan, Thailand, Assam, and the Malay Archipelago. (Drawn by Suzanne Runyan.)*

His description of the disease is a classic, in that it enables physicians to appreciate better the reaction of the human both in the course of the development of worms in the body and in their response when antimonials are administered to attempt a cure. As yet, the cure is almost worse than the suffering induced by the disease.

THE LIFE HISTORY (Figure 1) of the *Fasciolopsis* worm demonstrates quite a marvellous series of sequences. In biology, one tends to become very matter-of-fact in considering the passage of the parasite from host to host. However, the intricacy of the events and the sequences developed between humans and their parasites are usually quite striking. In this particular case it would seem that all of the activities of the humans in the endemic areas favor the worms. In the Shaohsing region, where Dr. Barlow did so much intensive work, more than a million people were seriously affected by this disease. Not only did many perish from it, but their efficiency was greatly reduced. The farmers in the area, covering some 1,600 square miles, usually become infected when they eat such raw foods as buffalo nuts (also called water caltrop, *Trapa natans*) and a so-called water chestnut (*Eliocharsis tuberosa*) on which the cysts of this parasite occur; they may also be encysted on lotus, water bamboo, and various other water plants.

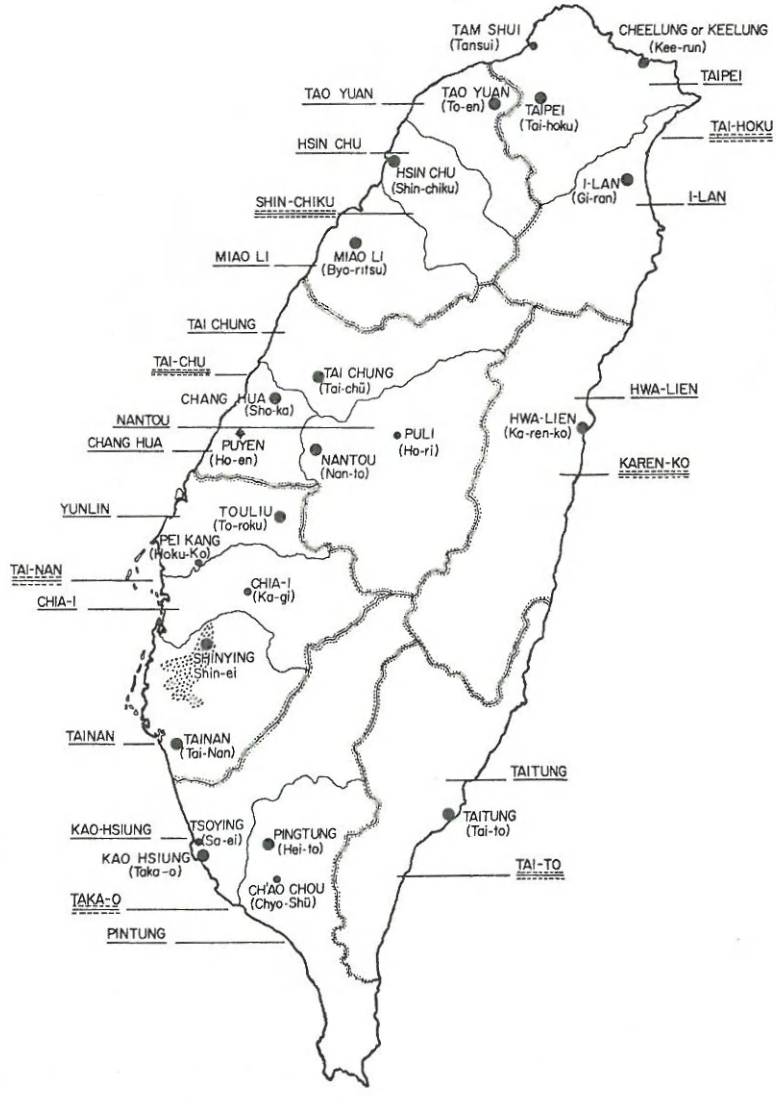
The caltrop nuts are cultivated in small ponds fertilized by night soil. The plants usually harbor small, planorbid snails which would easily be overlooked by those not aware of their presence. The fertilizer (raw human sewage) which is used contains eggs of this worm parasite. When the eggs reach water, a small larva (miracidium) hatches from the egg; it swims actively by means of cilia, finds the snails and burrows into one. In the snail the parasite goes through three larval forms to produce, in the snail's digestive gland (liver), a mobile larva (cercarium). Many cercaria are liberated into the water, and they promptly encyst on the husk of the water caltrop or on a tuber of the water chestnut (*Eliocharis tuberosa*). It takes about a month from the time the free-swimming larva (miracidium) enters the snail host until the free-swimming cercaria are liberated. The cercaria find objects on which to encyst almost at once.

The nuts (and tubers) usually come to the markets in July, and they are sold there as fresh nuts through September. The people prefer to eat them fresh. Throughout the growing season the nuts are apt to be dangerous, because the venders keep them moist by applying water with a brush; in this way they unwittingly keep the cysts on the nuts viable. When the nuts are dried, the larval parasites in the cysts that coat the rind are killed. Perhaps the most interesting feature in the process of human infection is the habit of the people to peel the nut with their teeth. The nut itself does not have the cysts, but the peeling process breaks an outer cyst wall to release the inner cyst into the mouth. These cysts then pass through the stomach, resisting the gastric juices, but on reaching the intestine they are digested and the larval worms released. Dr. Barlow reported finding as many as two hundred cysts on one nut.

LAST APRIL Dr. John Burch and I were able to spend a month (with National Science Foundation support) collecting snails on the island of Taiwan. It was possible for us, through the coöperation of the Naval Medical Research Unit at Taipei, to cross the island twice and to travel from the north end to the southern tip. With the able assistance of Captain Robert Kuntz and some of his well-trained assistants, we visited many of the best collecting grounds for snails that carry human diseases. There are some five snail-borne diseases that afflict the people there. Fasciolopsiasis is but one; some of the others include schistosomiasis, paragonimiasis (from raw crabs), clonorchiasis (from raw infected fish), and a marine fish-borne disease produced by Heterophyid flukes.

While it has as yet not been possible to study the several snails involved in these snail-borne diseases, it is clear from the

work of the Naval Medical group at Taipei that each of the diseases is localized and is limited largely to the region occupied by the snail intermediate host (see Map 1). Without mentioning the other regions with their specific infestations, the one in which fasciolopsiasis was most common was in an area surrounding a slaughter house near the town of Liu Ying. The pigs were killed and prepared for market in a small, open structure situated amid a series of ponds which were choked with aquatic plants. This vegetation was grown to be fed to the pigs. The life cycle in the pig is identical to that already described for humans in China, but here the parasite was especially favored in its infestation of pigs. The wastes at this slaughter house were usually washed with water from the ponds back into the ponds. The snails which serve as hosts were



MAP 1. FORMOSA (TAIWAN)

The Liu Ying area is a focal region for fasciolopsiasis, and is also endemic for the snail intermediate host (Segmentina).

legion on the aquatic vegetation, and the cysts produced by the cercaria which burrowed out of the snails encysted on aquatic plants. As might be expected, the pigs of this region were heavily infected. Humans there have only about a 3 per cent infestation.

An interesting problem has arisen with regard to the fasciolopsiasis occurring in China as compared with that in Taiwan. Dr. Barlow found that the parasite was entirely a human parasite in Chiang Province of China; he reported that this same disease in Taiwan appeared to be restricted to pigs. It has been of some interest, in this connection, to note that human blood fluke (schistosomiasis) in Taiwan also seems to be a non-human strain. While the reasons for these differences are, as yet, not well understood, it is fortunate for the inhabitants of this island that they are not as seriously afflicted with these diseases as are the inhabitants of China, so short a distance away. The Naval Medical Research Unit has data, from studies carried on over an extended period in Taiwan, to indicate that the human incidence in Taiwan is 24 per cent.

THE RELATION of a parasite to its host involves problems of specificity. It has been observed that the parasites will not penetrate all snails. There seem rather to be only certain species which carry some particular parasite. When one realizes that we hardly know the species of snails that occupy large regions, such as the island of Taiwan, it goes without saying that the details one needs to know about the particular habitats the specific snails occupy, their foods, their life history, and many other significant facts are legion. These must be known to enable reasonable methods of control of the intermediate hosts. It has long been recognized (as it also is in the case of malaria control) that the eradication of the vector or intermediate host usually proves most economical and most effective in rendering infested areas safe for those who must live in them.

The Museum of Zoology has attempted for many years to combine intensive field and laboratory studies which would enable a better understanding of the intricate problems involving a wide variety of animal groups. It has also been fortunate that over a long period some of the fields with interrelations have been stressed. Parasitological work done here through the efforts of Dr. George R. LaRue and his many excellent students have made our school outstanding. It is unfortunate that in recent years there has been a serious lag in the parasitological work, especially since the Ann Arbor region offers unusually good field opportunities. One need not go to the Orient to study paragonimiasis. One of Dr. LaRue's students, Dr. Donald Ameel, found a species of *Paragonimus* in the area of Ann Arbor. Another former student, Dr. Helen Price, studied a local schistosome parasite (one cause of "swimmer's itch" in Michigan) and her work served as a basis for much of the information needed for a better understanding of one of the most serious human diseases now extant, i.e., schistosomiasis.

Our University offers excellent training both in field and laboratory work. Unfortunately, in many schools there has developed a trend toward overemphasis of biophysics and biochemistry. This danger exists at Michigan as well. No one interested in the development of biology would wish to discourage any of the work in which physics and chemistry play an important role, but it would seem good sense to attempt to keep the stature our institution holds by maintaining its eminence in some of the significant aspects of field biology.

The importance of field training was clearly indicated in recent years, when one of Dr. LaRue's students decided to work intensively as a postdoctoral fellow in the University of Chicago. He wanted to use the well-known "swimmer's itch" parasite, *Schistosomatium douthitti*, which was studied, as mentioned above, by the late Helen Price, and which is found commonly in pools in the Ann Arbor region. When he left Ann Arbor he asked that he be supplied infected field-collected snails to be used in his work on immunology at the University of Chicago. The request for those snails never came, and when I saw him a year later he told me that he had

found all the infected snails that he needed for his work from the many pools at the Chicago city dump. It came as no surprise to hear that a very competent English-trained worker failed earlier in pursuing the problems studied by this LaRue-trained student, largely because he, like many people trained in Europe, was not capable of doing his own field work.

IT MUST BE insisted that there is a need for increasingly more field work. In our own country, just as in foreign lands, habitats in many rivers are rapidly being destroyed by power dams, silting, pollution, and so forth. It has been possible for me to study the mollusks in the local Huron River for some thirty years. A beautiful portion of this stream in the region of the Delhi rapids used to produce some fifteen species of fresh-water mussels and a wide variety of aquatic snails. During the war, a laundry at Dexter contracted to wash greasy rags for war plants in Detroit. That small laundry passed as much as a month's wastes through the Dexter sewage plant in a single day. About that time, one of my colleagues in Zoology asked where he might take a class to study a productive mussel bar in the river. When he reported that he and his class worked several hours in the riffles below the Delhi Mill, which site I had so confidently recommended, without finding even one live mussel, it became evident that there were casualties other than those produced in the battle regions.

Not only is there a need for concentration in field activities to obtain materials in areas that are about to be ruined by the plow or by pollutants in streams, but such work is vital as a basis of information to enable the culturing of species and groups to be used in laboratory work. Most of the work designed to find a drug to cure schistosomiasis now under way in leading pharmaceutical companies in our country and abroad is carried out by using a tropical snail (*Australorbis glabratus*) which can be cultured rather easily in laboratories. The drugs tested should then be useful especially against one of the human schistosome species, *Schistosoma mansoni*. The snails that carry the other two common human schistosomes, however, are difficult to culture, and must first be studied carefully under field conditions in order to understand better what is required for a successful laboratory culture program.

In our laboratory, intensive work (with Armed Forces support) has been in progress for seven years on snails that carry the Oriental blood fluke (*Schistosoma japonicum*). While we have gleaned some interesting information, we are far from knowing how we can culture these intermediate hosts to make a chemotherapy program as successful and efficient as that now carried on where *Schistoma mansoni* is studied. As a result of many field programs, it is now possible to provide a considerable amount of information about the ecology, distribution, morphology, and life history of these snails. Such studies, locally conducted on related Michigan snails, are just as valuable as the programs carried out by some of us in Egypt, the Sudan, Japan, the Philippines, and in Taiwan. Our studies show that Michigan snails considered as belonging to the genus *Pomatiopsis* are really not essentially very different from similar snails, in Japan, Formosa, China and the Philippines. In fact, the Michigan snails are congeneric with the Oriental ones, and it will be necessary for us to change the names of the intermediate hosts used in all medical and parasitological textbooks from *Oncomelania* to *Pomatiopsis*! Students in Public Health need not travel to the Orient to learn about the ecology of the snails that carry schistosomiasis and serve to infect millions of Oriental people.

IN THIS CONNECTION, however, it should not be assumed that field work is easy, even locally. Some time ago, a Public Health professor took some of his students out to show them local *Pomatiopsis* snails at a spot that had been carefully described to him over the telephone. The group failed completely to find those snails. It happened that they went at a season when the saw grass and other vegetation at the collecting site was high and thick; under those circumstances even a

trained collector, who knows just where the snails have been found previously, would have difficulty.

Such problems often occur in foreign regions. Scientists such as Dr. Robert Kuntz have travelled great distances to find the possible snail habitats responsible for foci of schistosomiasis infection in Malaya and Thailand. While many humans were demonstrated to have the disease in those regions, the snails that serve as intermediate hosts have not as yet been found. Field work exposes one to various hardships (heat, insect pests, short food rations, etc.); the collector must also often rely on experience and may even find that his discoveries have been made with quite an element of luck. Surely those of us who travel abroad for field studies are the envy of many of our friends and colleagues. The unusual experiences we have and the pictures brought back are without question deserving of envy.

Just before the war, I spent a year in Puerto Rico as an exchange professor at the University of Puerto Rico; during my spare time I made snail collections and later published a paper on the land and fresh-water mollusks of that island. Before leaving for Puerto Rico, I called on the then Dean of the Graduate School to request some funds for field work. He listened, then pulled out his pipe and stretched out on the couch in his office; from there he proceeded to tell me how wonderful it was for someone to go on a vacation with funds provided by the University! He was kidding, of course, but nothing would have pleased me more than to have had that dean (or any other!) with me on just one good, strenuous field trip!

To understand the animals better and to appreciate some of the intricacies involved in their culture, live material is increasingly being maintained in our laboratories. In this connection, we were fortunate to be able to bring the small planorbid snails (*Segmentina*) from some of the caltrop ponds of Taiwan. Fortunately they have cultured well. We also managed (through the Naval Medical Research Unit at Taipei, and the kindness of Captain Kuntz) to obtain eggs of *Fasciolopsis buski*. The eggs hatched here and we successfully infected some of the *Segmentina* snails. Since then the snails have shed cercaria which promptly encysted on the sides of aquaria and on the vegetation. Since it was impossible to find pigs to infect on this campus, it was fortunate that some of our friends and colleagues at Michigan State University kindly offered to allow us to infect two animals there. We have, as yet, not recovered eggs from the pigs but presumably that part of the cycle should succeed. If eggs of *Fasciolopsis* can be procured it will then be possible to study the specificity of this parasite, not only for its known snail intermediate hosts but for some of the hosts reported which really are circumspect. For example, one textbook implicates as an intermediate host a snail (*Lymnaea*) belonging to another family. *A priori* this possibility seems very unlikely, but one can not be sure of the host range or start work on any biochemical interrelations until a wide variety of snails have have been exposed experimentally.

FROM WHAT has been stated about the fasciolopsiasis parasite, its snail hosts and the laboratory studies involving it at such places as the Taipei Naval Research Unit and our own Mollusk Division in the Museum of Zoology, one would quite rightly assume that some of the technical aspects of this disease and its relation to man are reasonably well understood. However, the following statement by Dr. Claude H. Barlow clearly stresses some of the difficulties inherent in eradication in underdeveloped regions:

> In considering the factors involved in the eradication of fasciolopsiasis from the endemic area, one must take into account the conditions peculiar to the region, which affect the life, laws, customs, and religion of the people. The problem is a complicated one, aside from the difficulties encountered in the control of any parasitic disease, from the side of the parasite itself. The latter is formidable enough, but its difficulties pale into insignificance beside those presented by the people. They are poor, ignorant, suspicious, indifferent, and superstitious.

Dr. Barlow gave a most interesting and stimulating seminar in 1929 at our Biological Station on his experience in China. He came away from China feeling somewhat defeated, and stated that eventually it would be up to the people themselves to learn to avoid infection with this parasite. It became especially frustrating when patients who had taken a course of treatment and who had been reminded repeatedly to avoid eating raw caltrop nuts would come back to the clinic three months later with new and heavy infestations.

The need for better integration of interests when organizations work in underdeveloped regions has long been evident. The same kinds of problems were present in Egypt, where there is great need for alleviating suffering brought about by the very high incidence of schistosomiasis. Our studies there under World Health auspices indicated that in many villages every inhabitant harbored that disease. It is conservatively estimated that at least fourteen million of the twenty-five million people in Egypt are infected. Yet, many of the projects initiated and financed with funds from our country were clearly without any semblance of integration. These problems, whether they concern malaria, fasciolopsiasis, schistosomiasis, or other such diseases, must be the concern of others besides the local health authorities. While there is far more emphasis in the world today on social problems and economic welfare, the failure on the part of all of us to encourage people in their villages to attack their problems on a wide front is obvious. Such a need for integration also exists in local communities in the United States and organizations, including the University, but nowhere does it assume the prominence and importance that one finds in the underdeveloped regions of the world.

TWO FRIENDS of mine recently visited the area of the new High Dam at Aswan in Egypt. They reported that in the regions of the coffer dams malaria had developed at an alarming rate. With modern techniques for the control of malaria there is no reason to neglect that aspect of the work, but in spite of the knowledge available for mosquito control, people will not follow instructions and the units responsible for legislation and coördination of effort too often fail to function.

In this same vein, a similar situation developed in Egypt when we were applying a molluscicide to kill snails in a large canal. The schedule on that particular canal called for high water, which is what was needed to insure that the snails higher up on the banks would be exposed to the copper ions used to kill them. The job involved a three-day program. The first day everything went off very well, but the next day, when we came to apply the chemical (copper sulphate), we found that the water, contrary to the regulation, was off and the level had dropped to a point where the molluscicide could not be applied. The response of the engineer in charge of that region to our protest was the characteristic "Never mind!" He was only trying to satisfy a request of an influential friend and in due time the situation would be remedied! Incidents of this kind are legion. The new High Dam at Aswan in itself is a good illustration of an endeavor which fails to take into account a health hazard that will ensue after this dam is completed and in operation.

If the foregoing has in some measure stressed the importance of integration and team work, the purpose of this article will have been achieved. To obtain a measure of coördination, when working in underdeveloped regions, is apt to be a slow and frustrating process, largely because of the variety of differences inherent where the mores, cultures, and languages are often foreign to us. When I stressed some of these difficulties in a talk not long ago to students interested in the Peace Corps, one young lady came up afterward to tell me of her experience as a member of another group the previous summer. She was one of fifteen college students sent to Senegal to teach the natives how to use cement in their villages. After discovering what a native village was really like, only half of them would go to work there—the rest played cards in their barracks. After one day in the village, the whole group retired to their bar-

racks to spend the remainder of the two-week assignment playing cards! It is evident that beyond the technological aspects, much remains to be accomplished in bringing a semblance of coördination between fields, particularly when one attempts to work in foreign regions.

The important role of staff members on this campus who have had so many and such widely diverse experiences abroad is generally not appreciated, and these people are widely scattered throughout the many departmental units of our school. Not only could they serve to brief students and colleagues who are contemplating foreign assignments, but they would help to insure better liaison among those on campus who have an interest in a wide variety of foreign services. Suggestions that some effort be made to learn about their experiences have been made to President Hatcher by a Committee for International Relations which met to discuss and make recommendations along this line a year or two ago. This resource is at present so badly scattered and unorganized that it is not now generally available.

HUMAN INFLUENCE usually proves more difficult to cope with than technological problems themselves in disease control, although the latter are often difficult enough. There are many facets of human endeavor that need alignment if progress is to be made in correcting many economic and social conditions, as well as in the problems of health. While these interrelationships are usually more clearly defined in underdeveloped regions, there is need for an awareness of them in training programs on campus as well as in foreign aid programs. A survey course, using all available facilities in a school, might well be given so as to provide knowledge of fields other than the specific one in which each person has been trained. As the late Professor Kraus of the Netherlands observed after he had made a mental health survey in Egypt:

> Another reason was the lack of close cooperation between all kinds of services. This point has been mentioned already in several other reports to WHO on surveys in Egypt, but it seems necessary to lay stress on it again. There is not sufficient coöperation between the various ministries, departments, or even sections of the same department. Also, coöperation between governmental services and private agencies leaves much to be desired and the same holds true for coöperation between private societies. A great many of the 3,000 private societies in Egypt having social activities in their programme have never heard of activities of the others working in the same field. This lack of close coöperation is detrimental of course to efficient working and means a loss of time, energy and money. It has been said again and again that there remains still a tremendous lot to be done in fighting against Egypt's three great evils: poverty, illiteracy, and disease, and this is undoubtedly true. But I can not help saying that many times I got the impression that too much is being done or rather too many things are being done. Attention should be focussed on a few things, problems must be more vigorously tackled at their root, which in my opinion is poverty above all.