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A Study of the Environmental Aspects of Schistosomiasis in Libya

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A STUDY OF THE ENVIRONMENTAL ASPECTS OF SCHISTOSOMIASIS IN LIBYA

by

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A STUDY OF THE ENVIRONMENTAL ASPECTS
OF SCHISTOSOMIASIS IN LIBYA

Abubaker I. Swehli, Ph.D.

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Schistosomiasis is a serious disease in humans. Two species of schistosome, Schistosoma mansoni and Schistosoma haematobium, organisms that cause the disease, parasitize humans in Libya. Schistosomes require aquatic snails in their life cycle. The purpose of this study was to investigate the environmental and the host relationships of the disease in the three regions of Libya where the disease is found. These relationships include:

1) Analyses of the physical-chemical characteristics of the aquatic habitat.

2) Collection of snails to determine: a) the kind of snail species and their abundance; and b) the cercarial infestation rates.

3) Infection rates in humans.

4) A search for relationships among factors that appear to be significant in the distribution of the disease.

Biomphalaria alexandrina or Bulinus truncatus, the intermediate host snails for Schistosoma mansoni and Schistosoma haematobium, were the most abundant species of snails in all three locations of the endemic foci - the Mizurata region, the Derna region, and the Fezzan region. In the Mizurata region, 1,742 Biomphalaria snails were found among 2,559 snails. In the Fezzan region, 907 Bulinus snails were found among 968,

and in the Derna region, 75 _Bulinus_ snails were found among 202. The incidence of cercaria in snails was found to be 0.63% in the Mizurata area, 0.44% in the Fezzan region, but none of the _Bulinus_ snails in the Derna region were found to be infected.

Infection rates in males vary with age, region, species of schistosome, and history of residence. The infection rate among students with _S. mansoni_ in the Mizurata region was found to be 65%, whereas the rate in the adult male population was 18.34%. The _S. haematobium_ infection rate among adults in the Fezzan region was found to be 9%, and in the Derna region it was 8.5%. Non-Libyans working in the Libyan agricultural regions had infection rates averaging about 40%, whereas Libyans in the same region had rates of infection averaging about 9%.

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CHAPTER I

INTRODUCTION AND GENERAL INFORMATION ABOUT LIBYA

Schistosomiasis is one of the most serious parasitic diseases of humans living in the warmer regions of the world; it is of special concern because many people are affected and many deaths are caused by the parasite. The purpose of this study was to investigate certain of the environmental aspects of schistomiasis in the hope that the knowledge gained will lead to a practical application in controlling the disease. Because the disease includes a snail host in its life cycle, many aspects of the biology of snails and of humans could be important determinants in the control of the disease. Therefore, the problem was examined broadly in order to discover some of the ways for controlling the disease.

The disease is found in some regions of Libya, whereas in other regions it is absent. This study is focused on regions where the disease is found. In addition to geographic factors, the biology of snail hosts and the biology of the schistosome parasites, schistosomiasis and its control involve many social, health, educational, and economic factors relating to the human host. The following material describes some of these factors in some detail.

The Socialist People's Libyan Arab Jamahirya (Libya) is situated in North Africa (Fig. 1), has a Mediterranean coastline of 1,900 kilometres, and an area of about 1,760,000 square kilometres. Libya is

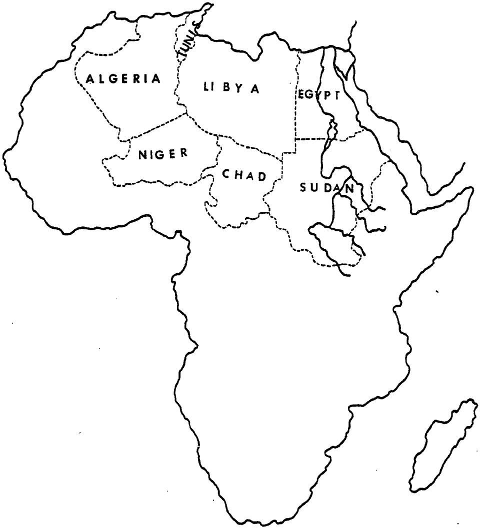

Fig. 1. Map of Africa showing Libya and neighboring countries.

the fourth largest country on the African continent. The terrain is composed of coastal plains, hills, mountains, and deserts. The Libyan coastal plain has the most fertile lands and highest population density. It extends over a vast territory inland from the central Mediterranean coast of North Africa to the highlands of North Central Africa. It is bounded on the north by the Mediterranean Sea, and on the east by Egypt and Sudan. On the south, it borders Niger, Chad, and Sudan. In parts of the south and west, it touches Algeria and in the northwest, Tunisia. Libya has a particularly strategic position, since, as a link between Africa and Europe, it is a potential dispersal route for schistosomiasis.

The climatic conditions of Libya are influenced by the Mediterranean Sea to the north and the Sahara to the south. In general, the country has a temperate climate, with the temperature higher toward the south and lower in the mountainous regions.

Social Aspects

People and Population

Most of the people in Libya are Arabic-speaking Muslims of mixed Arab and Berber origin. There are also some Berber-speaking people in northern Libya and in the desert region. The population is comprised of nomads, semi-nomads, and settlers. Small groups of Tuareg tribesmen are found in the southwest, especially at the Ghudamis and Ghat oases. Traditionally nomadic, the tribesmen are gradually assuming a sedentary lifestyle. Some of the populations of the isolated Teda (Tebu) Tuareg communities of the southeast are gravitating toward the north and Al-Kofra Oasis in search of employment.

Health

According to the 1954 census, the population of Libya was 1,088,889, with a birth rate of 5.3% per year. However, the natural growth has been kept down to 1.1% because of high infant mortality that reflects the poor quality of the Libyan diet and the lack of health education and services. The Libyan's historical record of poor medical health care is related to the underdevelopment and poverty of the country. Endemic and epidemic diseases such as trachoma, tuberculosis, malaria, and bilharzia were widespread. The International Bank for Reconstruction and Development (1960) reported that in 1950, the per capita income was less than 14.29 L.D. ($48.00) per year. The caloric content of the average diet was 1,300 calories per person per day.

Public investment for health programs has been growing rapidly since 1962. The expenditure on health services increased from 2.222 L.D. ($7,466 million) in 1962 to 5.4 L.D. ($18,144 million) in 1971. The total health expenditure during the three years 1973-1975 reached 81.00 L.D. ($272.16 million). During the five year plan, 1976-1980, the total health expenditure reached 200.5 L.D. ($561.4 million).

Physical Aspects

Temperature

Temperature records indicate how the sea and the desert influence the weather and climate of Libya. The effect of the desert on temperature is paramount, however, and the highest temperatures in the coastal regions are caused with southerly airstreams from the desert. The sea exerts an important influence for only a relatively short distance inland and causes lower temperatures than found in the inland regions. The difference is from 10°C to 20°C during the hot season. Altitude has a great influence on reducing temperatures in the northern mountains in Libya. The influence is greater in the winter season than in the summer season.

Libya can be divided into three regions: 1) Mediterranean coastal lands, 2) the coastal mountains, and 3) the desert. The Mediterranean region is hot and relatively dry in summer, but warm and wet in winter. The temperature ranges from 46°C to 7°C. However, at Azizia, 30 kilometers from the sea, a high temperature of 58°C and a low temperature of -3°C have been recorded. In the mountain regions, the average temperature during the summer season may be as much as 50°C with a mean minimal winter temperature of -5°C.

Winds and Humidity

Along the coastal region, moisture-laden winds from the Mediterranean Sea contribute to the ability of this region to support the level of vegetation found there. In some regions adjacent to the sea, winds carry salts that limit the types of crops that can be grown. The important wind, from the standpoint of its effect on vegetation, is the hot and extremely low relative humidity wind that blows from the desert. These winds, locally called "Gibli," can last five days, but seldom persist for more than 24 hours. Gibli winds dry the soil and frequently parch the vegetation. If they occur during the growth period of the plants, the effects on yields may be disastrous. A Gibli, during the early stage of growth of a cereal, often makes the difference between a good harvest and a bad one. If it blows when almond trees are in the pollination stage, it may drastically curtail the crop. In the southern region where the humidity is low, especially during the summer, a few days of high velocity winds may ruin many of the vegetable crops. During the fall season, there is one redeeming feature of the hot dry winds that sweep the western part of the coastal area--they may damage other vegetation, but the date crop benefits. If the winds fail to come in the fall, the date crop may not mature properly, and both total production and quality are decreased.

Rainfall

According to the Secretariat of Dams and Water Resources (1977), the total surface of the country receives 42,949 million cubic meters of total annual rainfall volume in average years. However, the average depth of rainfall in Libya is less than 100 millimeters (mm) per year over 93% of the country land surface. The area of the western region represents 16% (281,440 km^2) of the total surface of Libya and receives 36% of the total volume of rainfall in the average year. The average depth of rainfall over the western region for 17 years is 54 mm with some regions with a total area (246,260 km^2) receiving about 27% of the total rainfall volume. The average annual depth of rainfall values for the period of 17 years of records was about 48 mm. The central region of the country represents 7% of the total surface (123,130 km^2) and receives 17% of the total annual rainfall volume in the average year. The average annual depth of rainfall in this region is about 60 mm. In the southern region, the average annual depth of rainfall is 8 mm.

Runoff

Most of the runoff water evaporates or infiltrates the valley (wadi) beds and the spreading zones distributed along the foot of the mountains before reaching the sea. The Secretariat of Dams and Water Resources (1977) estimated that 10% of the surface runoff reaches the sea, although this is decreasing due to construction of storage dams. In Libya there are many existing dams, with some under construction. The proposed dams have a storage capacity of less than 2.0 million cubic meters per year. When all planned dams are operational, the mean quantity of water stores will be about 50 million cubic meters per year. This value is relatively small when compared with the total water consumption of Libya.

Ground Water

About 95% of the total water supply in Libya is obtained from ground water reservoirs. Part of it can be considered as renewable from the rainfall recharge, whereas the other part is nonrenewable due to the shortage of rainfall in the region. Therefore, the available ground water in that region is considered to be a fixed amount stored in the ground during the last thousand years.

In the Gefara plain the total annual recharge of the aquifers is estimated at 300 million cubic meters. When considering the possibility of using the reserve, the actual groundwater resources might be estimated to 450 million cubic meters per year. This amount, if extracted, would lower the water table about one meter per year. The water quality of the shallow aquifer of the Gefara plain is good when it is not affected by sea water intrusion. The total dissolved solids (TDS) range from 500 to 1000 ppm.

In the western region, groundwater recharge at the present time, occurs only in the northern part. The water quality of this region is good to excellent. The total dissolved solids are estimated to be between 500 and 15,000 ppm. In some regions, brackish aquifers may be encountered mainly in the shallow horizons when evaporation produces a salt concentration. The main limiting factor to the groundwater development in this region is the excessive cost of pumping when the drawdowns produced by an excessive extration are too high.

In the eastern region (Jabat El-Akhdar), precipitation infiltrates the calcareous layers. It flows either to the sea or to the southern part where it becomes saline. The amount of the available water in the southern part is estimated at 150 million cubic meters per year and in the northern part approximately 250 million cubic meters per year. The great depth of the water table in most of the southern part and risk of sea water intrusion in the northern part limit the regions where water can be extracted. The water hardness of this system varies from 1000 ppm in the crestline to 4000 ppm in the coastal areas and in the southern part of the region.

The groundwater reservoir in the southern part of the eastern region consists of very thick layers of sandstones. It is more than 3000 meters (m) deep in the center of the Kufra region. The groundwater recharge comes from the south as a result of slow emptying of the huge sandy reservoirs filled up with fresh water during the pluvial episodes of the Quaternary Period (Secretariat of Dams and Water Resources, 1977). Most of the groundwater resources in the southern part of the eastern region are connected with the huge storage capacity of the thick sandy reservoirs that are saturated with fresh water over an area of about 400,000 km^2. The estimated amount of water that can be extracted annually is 1500 million cubic meters. The water is relatively soft in the Kufra basin (less than 500 ppm) and only slightly harder in the Sarir basin (500 to 1500 ppm). The water quality deteriorates as the groundwater extends to the north or west of the region.

The field investigation of this study involved comparisons of the several factors just discussed for the three regions of Libya where disease is endemic. The three regions are Mizurata, Derna, and Fezzan. The following activities were undertaken:

1. An analysis of the physical-chemical characteristics of the aquatic habitat.
2. A study of snail's species and their abundance.
3. A determination of infestation rates in snails.
4. A determination of infection rates in humans.
5. A search for relationship among factors of significance in the distribution of the disease.

CHAPTER II

LITERATURE REVIEW

Schistosomiasis

Schistosomiasis is often called bilharziasis. It is a parasitic disease caused by a flatworm that uses humans as final, definitive hosts. It is believed that about 250 million people in the world are infected with this disease (World Health Organization, 1980). Most of the infected people live in agricultural communities in many different parts of the world. There is no known way of immunizing people against contracting the disease.

In 1851, Dr. Theodore Bilharz, who was Professor of Anatomy at the medical school in Cairo, was the first to discover the disease. Bilharz announced his discovery in a letter to his former teacher, Von Siebold, naming the parasite *Distomum haematobium*. The name "bilharziasis" commemorates his discovery (Hegner et al., 1938). In 1858, Weinland of Harvard University renamed the worm *Schistosoma*, which means split body (Schmidt and Roberts, 1981). This name refers to the body of the male worm that is split, divided, or folded over to form a groove or channel in which the female lies throughout its adult life. Today, the disease is known in South America and in the Far East as schistosomiasis, and in Africa as bilharziasis.

Data obtained from different countries of Africa and the Middle East indicate that an increasing prevalence of schistosomiasis is related to water resource development (Sturrock, 1965). The concern has been shown by some of the African and Caribbean states where tourist attractions are adversely affected by the possible hazard of schistosomiasis from using the water of lakes, reservoirs, and rivers situated in endemic areas.

The World Health Organization has shown an interest in the problem of schistosomiasis and its control through sponsoring Expert Committee meetings, conferences, and groups studying problems related to control of the disease.

Human Schistosomiasis

The schistosomes, or blood flukes, that cause schistosomiasis in humans, are digenetic trematodes that belong to the superfamily, Schistosomatoidea. There are three types of schistosomes that cause schistosomiasis in humans (Table 1 and Fig. 2). *Schistosoma haematobium* causes the urinary type of the disease that is distributed widely in Africa. *Schistosoma mansoni* causes the intestinal type of the disease that is also endemic in many parts of Africa. *Schistosoma japonicum* is the eastern type that affects the intestine. It is found in China, Japan, and other countries of the far East but is not established in Africa.

A schistosome trematode needs an intermediate host, a snail, for completion of its life cycle. The snail host is different for each type of schistosome. With *Schistosoma haematobium*, the urinary type, any species of the genus *Bulinus* may serve as a host. *Schistosoma mansoni*, the intestinal type, requires a species of *Biomphalaria* as

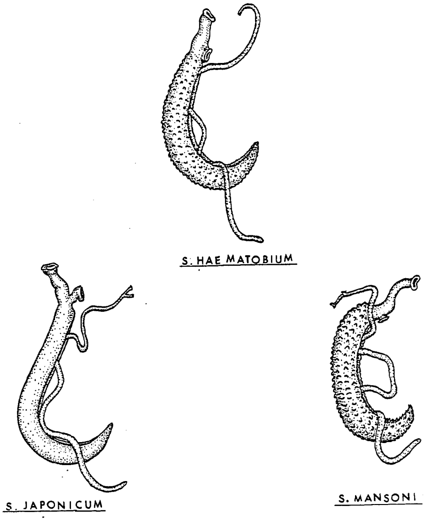

Fig. 2 Adult schistosomes

Table 1
Comparative Morphology of the Three Types of Human Schistosomes

Characteristic	*S. haematobium*	*S. mansoni*	*S. japonicum*
Tegumental papillae	Small tubercles	Large papillae spines	Smooth
Size			
Male			
Length	10-15 mm	10-15 mm	12-20 mm
Width	0.8-1.0 mm	0.8-1.0 mm	0.5-0.55 mm
Famale			
Length	ca 20 mm	ca 20 mm	ca 26 mm
Width	ca 0.25 mm	ca 0.25 mm	ca 0.3 mm
Number of testes	4-5	6-9	7
Postition of ovary	Near midbody	In anterior half	Posterior to midbody
Uterus	Few follicles, posterior to ovary	Few follicles, posterior to ovary	In lateral fields, posterior quarter of body
Egg	Elliptical, with sharp terminal spine; 112-170 m x 40-70 m	Elliptical, with sharp lateral spine; 114-75 m x 45-70 m	Oval to almost spherical; rudimentary lateral spine; 70-100 m x 50-70 m

Source: Schmidt, G. and Roberts, L. 1981. Foundation of parasitology. St. Louis: Mosby, p. 253.

a host. In the case of Schistosoma japonicum, the intermediate host is a species of Oncomelania.

Schistosoma mansoni

Schistosoma mansoni has been found in Libya, and is endemic in the region of the Nile delta. It is also widespread in the Khartoum region in the southern part of Sudan. It occurs in Eritrea, Uganda, Kenya, Mozambique, Tanzania, Rhodesia, and Zambia. In West Africa, it is distributed from Senegal and Gambia to the Cameroons and to Lake Chad. In the Middle East, S. mansoni occurs in Yemen, Southern Yemen, and Saudi Arabia. In the western hemisphere, S. mansoni is endemic in Venzuela, Puerto Rico, Brazil, and the Dominican Republic.

In 1902, Manson found lateral-spined eggs in the feces of a patient from the West Indies. He mentioned the existence of a second species of blood fluke. Looss (1905) disagreed and explained that the lateral-spined eggs were S. haematobium eggs produced parthenogenetically in the absence of males. Sambon (1907) rejected the hypothesis of Looss and named the new species after Manson. Leiper discovered this intermediate host in Egypt in 1915.

Schistosoma mansoni is smaller than S. haematobium. The length of the male is 6-13 mm. and the female, 7-17 mm. The male has 4-13 testes. The ovary of the female is located anteriorly. A short uterus occupies the anterior third of the body. It usually contains only one or two eggs at a time. Mature worms are found in the inferior mesenteric vein of the human and their eggs pass into the lumen of the bowel and are discharged with the feces. Each egg has a yellowish-brown transparent shell with a lateral spine. The eggs are about 112-175 um long with a diameter of about 45-70 um and are usually mature when passed in the feces. A female can produce 100-300 eggs per day.

Dysentary is common in S. mansoni. Other symptoms include abdominal pain, bloody mucus in the stool, and the development of general fibrosis in the bowel wall. With S. mansoni and the other species, eggs lodge in the liver, spleen, and lymph glands. The spleen and liver become greatly enlarged and anemia develops. The liver is often damaged by cirrhosis.

Schistosoma haematobium

Schistosoma haematobium is found in North Africa including Morocco, Algeria, Tunisia, Libya, and Egypt. It is widely distributed throughout most of the African continent including Somalia, Malagasy, Mauritius, in large regions of Central Africa, and in West Africa from Nigeria to Angola. It has been reported, also, in South Yemen, Saudi Arabia, Lebanon, Iraq, Iran, Syria, and India.

This species produces a chronic disease characterized by the presence of blood in the urine and infection of the bladder. This has occurred in Egypt since the time of the Pharoahs as shown by the calcified ova found in the kidneys of two Egyptian mummies. The symptoms of the disease were found among the French troops during their invasion of Egypt in the beginning of the 18th century.

Leiper (1915) identified the intermediate host of S. haematobium in Egypt, by exposing mice to cercariae from Bulinus and demonstrating that the mice developed worms that produced terminal-spined eggs. The River Nile was the original center of distribution of S. haematobium from where the infection has spread to other regions.

The adult worms of S. haematobium inhabit the veins of the vesical plexus of humans and some live in the portal vein and its mesenteric branches. The male worm measures about 10-15 mm in length and 1.70 mm in breadth. The female is longer and more slender than the male, and measures about 20-26 mm by 1.25 mm. It is usually darker than the male with more blood pigment in the gut. The ovary is located in the posterior third of the body. Ten to 100 eggs develop at a time in the long uterus. Faust (1948) indicated that eggs are partly mature when laid, migrate through the bladder wall, and are discharged in the urine. The eggs have a yellowish-brown transparent shell with a terminal spine. Pitchford (1965) reported that S. haematobium eggs measure about 83-187 um in length, and one female can produce between 20-290 eggs per day.

Symptoms and pathology in schistosomiasis caused by S. haematobium are similar to those caused by S. mansoni, except that the urogenital tract is affected, rather than the bowel wall. Early symptoms consist of headache, loss of appetite, and fever. The liver and spleen are hypertrophied, and the abdomen becomes enlarged. The mucous surface of the urethra becomes inflammed and cirrhosis of the liver may develop.

Schistosoma japonicum

Schistosoma japonicum is endemic in China, Japan, the Philippines, Thailand, Laos, and Vietnam. It has been reported that S. japonicum is found in lower animals in Taiwan, but no human cases have been recorded.

Katsurado (1904) named the species Schistosoma japonicum and gave an accurate description of the eggs found in humans and cats. He found that dogs, horses, cattle, and cats could serve as hosts of the parasite. Faust and Meleney (1924) discovered the intermediate host, Oncomelania, in China.

Other Schistosomes of Lesser Medical Importance

Schistosoma intercalatum

Fisher (1934) described the terminal spined eggs of the schistosome found in feces of people in the Congo. The eggs measure about 140-240 um by 50-80 um. Schwetz (1956) indicated that sheep and goats are important reservoirs. Chesterman (1960) succeeded in infecting sheep experimentally with the schistosome.

Schistosoma bovis

This type of schistosome was first described in cattle in Egypt. The adult worm is larger than that of S. haematobium, with larger but narrower eggs with a prominent central bulge and terminal spine and these eggs are about 130-260 um in length. The schistosome is a common parasite in the mesenteric portal system of cattle and sheep of southern Europe, Africa, and Iraq. A few cases of S. bovis were discovered in people in Uganda, Rhodesia, and South Africa.

Schistosoma mattheei

This type of schistosome is found in domestic and wild animals in Southern Africa. The hosts include cows, sheep, horses, babboons, zebras, and a wide variety of antelope. Humans are more susceptible to S. mattheei than to S. bovis. Nelson, Teesdale, and Hightou (1962) reported that S. mattheei is always found in patients infected with S. haematobium or S. mansoni. They suggested that it may not be well adapted to humans and the female worm may require the males of one of the other schistosomes to transport it to a site for egg laying. Eggs in the feces or urine measure about 120-280 um in length and have a terminal spine.

Schistosoma rodhaini

This species of schistosome is related to S. mansoni. It has been found in wild rodents and carnivores in African countries including the Congo, Kenya, and Uganda. The egg has a subterminal spine. Schwetz (1956) indicated that S. rodhaini is really a S. mansoni found in rodents.

Schistosoma margrebowiei

This parasite has been found in antelopes in central Africa. It has smaller eggs than S. mansoni. It measures about 65 um by 43 um and does not have a lateral spine.

Schistosomal dermatitis has been known to exist for more than a century. It can be caused by several flukes that have a similar life cycle to the other types of schistosomes, but use birds or mammals rather than humans as definitive hosts. Swimmers' itch results when the larva of the parasite (cercaria) penetrate the skin of sensitive individuals. The parasites die, but cause an allergic reaction. Red spots appear at the point of entry. The diameter of this area increases because of the itching. This may be accompanied with a fever and nausea. After a week, the symptoms usually disappear.

When cercariae contact a suitable aquatic bird or mammal, such as a rodent, they penetrate the skin and continue to migrate in the blood vessels of the host. The parasites become adults in veins that surround the intestine. The female worm lays eggs that work their way into the opening of the intestine. When the bird defecates into the water, the eggs of the parasites hatch into a free swimming stage (miracidia). These larvae penetrate snails such as _Lymnaea_ and _Physa_, completing their life cycle. Blankespoor (1980) reported that the use of copper sulfate with fresh hydrated lime (with a ratio of eight parts copper sulfate to one part hydrated lime by weight) has given good results in eradicating snails, thus eliminating the swimmers' itch problem.

The Life Cycle

The three species of schistosomes, _S. haematobium_, _S. mansoni_, and _S. japonicum_, that infect humans have similar life cycles and develop over a succession of stages--egg, miracidium, first-stage sporocyst, second-stage sporocyst, cercaria, schistosomule and adult (Fig. 3). The basic life cycle involves an alteration of generations, with the sexual generation of adult schistosomes being in the definitive vertebrate host and the asexual stage in a molluscan host. The usual place of entry is the skin. The cercariae, after penetration and loss of the tail, are known as schistosomules that migrate and develop into mature adult schistosome worms.

Although the three species of human schistosomes have similar basic life cycles, they differ in the morphology of the adults (Fig. 4), the shapes of the eggs (Fig. 5) and larvae hatched from the eggs, and the intermediate host snails.

The adult male and female are generally paired. The adult female lies in the gynocophoral channel of the male, into which sperm seem to be extruded through a pore below the ventral sucker. The sperms enter the female duct and accumulate near the ovary until fertilization of eggs occur (Kitajima et al., 1976).

The female lays chains of small bead-like eggs, in the mesenteric or pelvic veins of the human. These eggs, containing larvae, are deposited in small blood vessels of the bladder or intestine, where many penetrate the blood vessel walls, and according to the type of worm, are passed out of the body with urine or feces. Miracidia develop inside the eggs during their passage through the intestinal or bladder wall. They are motile and ready to hatch when the eggs are voided.

In warm water, after one minute to as much as sixteen hours, each egg hatches into a miracidium. Hatching is caused by osmotic effects

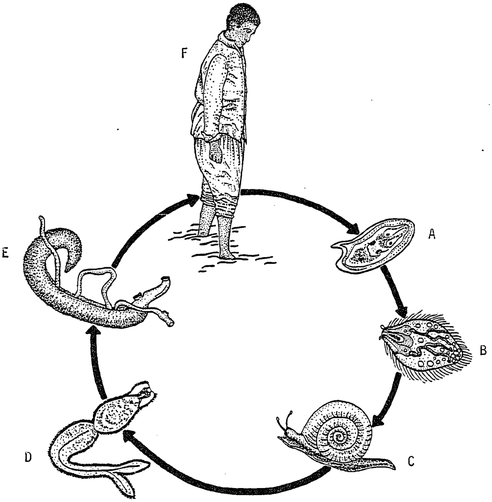

Fig. 3. The life cycle of schistosome. A, egg shed in urine or feces; B, miracidium penetrates an aquatic snail, C; D, cercaria escape from snail and develop into the adult fluke, E, in the blood vessels of the human host, F, after cercaria, D, penetrates the human in contact with contaminated water.

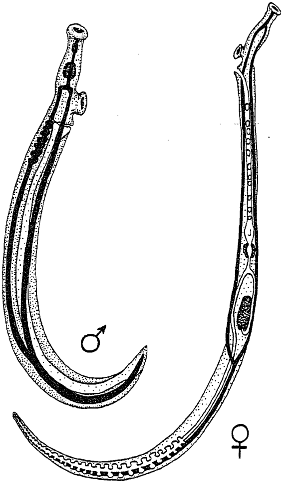

Fig. 4. Adult male and female schistosomes.

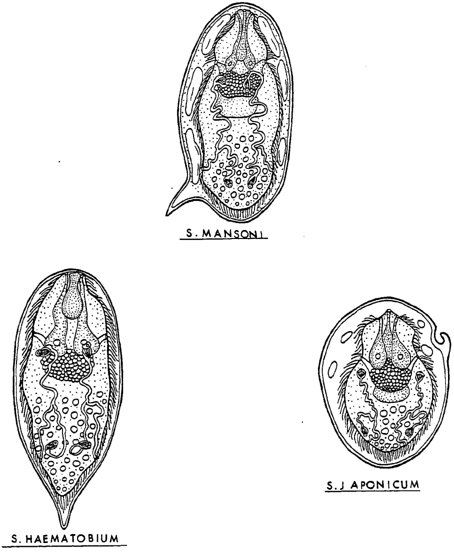

Fig. 5. Eggs of schistosomes.

and the activity of the larvae. Light plays an important role in the hatching process (Bair and Etges, 1973). Kassim and Gilbertson (1976), however, failed to find a significant difference between hatching in light and hatching in darkness, and indicated that ionic composition of the medium does not seem to have an effect on hatching.

The miracidum is a larval form with hairlike projections, called cilia, that enable it to move through water and reach the upper layers of water bodies where a large portion of the molluscan hosts are usually located. The miracidia appear to swim and search for a particular kind of snail in which they may continue to develop. They have only 24 hours to find one, since their stored food supply will only last that long. Mason and Fripo (1977) indicate that changes of the reactions of miracidia to light are related to changes in temperature. Wright (1971) found that the movement of the miracidia to the water surface is a positive response to light - a negative response to gravity. Objects in the water that reflect sunlight will attract the miracidia to their submerged edges (Cherin, 1974). The motility of miracidia depends on the presence of Na^+ in the medium (Kassim and Gilbertson, 1976). Etges and Decker (1963) reported that miracidia may be attracted by mucus secreted by the snail host. Shift (1969) reported that several factors influence the infection of snails by miracidia, including the number of miracidia per snail, the dispersion of snails and miracidia, the temperature of the habitat in which they live, the length of contact time, the water flow and turbulence, and ultraviolet light. The infection rate of snails increases with increasing densities of miracidia. Purnell (1966) indicated that the penetration of Biomphalaria snails by S. mansoni miracidia and the infection rate in snails increases with increasing temperature up to the thermal death point of snails.

When the miracidia reach suitable snails, they attach themselves to the soft tissues of the head, foot, or tentacles, bore into the snails, and migrate to the digestive glands.

There are delicate relationships between miracidia and their snail hosts. Wright (1967) indicated that "in many cases it is so strain specific that development of the next larval stage will not occur even in an unusual strain of the normal host species." Pan (1965) had studied the host parasite relationship and tissue responses in B. glabrata infected with S. mansoni and indicated that a small portion of the miracidia that enter the snail host develop into mature mother sporocysts in the head-foot of the snail. Then, the miracidia grow into sporocysts that are hollow, saclike organisms with germ cells on the outer wall. Each sporocyst buds off a number of secondary sporocysts (about 30) similar to the first. The secondary sporocysts are opaque and have a spine covered anterior end. They migrate to the connective tissue of the snail's liver where further production of germ balls takes place and the final larval form of cercaria is produced. Each secondary sporocyst produces about 40 forked-tail cercariae. A high mortality of snails is noted at this time. The cycle within the snail intermediate host, after penetration of the miracidium larva until production of the cercariae, takes about 4-5 weeks for S. mansoni, 5-6 weeks for S. haematobium, and 7 weeks or longer for S. japonicum.

The cercariae of human schistosomes are similar. They lack eye spots and a pharynx and are less than 1 mm long. They have a small ventral sucker and a muscular, eversible sucker that occupies one third of the body. The body of the cercaria is covered with spines and hairs that are concentrated on the acetabulum and along the anterior sixth of the body. The digestive system has a mouth located in the center of the oral sucker, an esophagus, and a pair of short dorsally placed caeca. The nervous system consists of a mass of nerve fibers. The excretory system has three pairs of flame cells, collecting tubules and an excretory bladder.

McClelland (1965) had studied the production of cercariae and reported that at a "temperature between 10°C and 30°C and possibly higher, light is the principal stimulus causing the release of cercariae of both S. haematobium and S. mansoni." S. mansoni cercariae are shed in small numbers in the dark. Smyth (1966) reported that mass emergence of cercariae appears to be limited to a pH range of about 6.5 to 9.5.

Webbe and Jordan (1966) reported that their study in Tanzania has shown that the peak of the S. mansoni cercarial shedding period occurred between 10 A.M. and 2 P.M. in a natural water-course.

The number of cercariae varies from one day to another and is related to the susceptibility of the snail to infection. The number of cercariae shed increases until it reaches a constant daily level that usually is maintained until a short time before the death of the snail, or when the snail is cured of the infection. African Biomphalaria ssp. shed up to 1,000 cercariae per day, and B. glabrata shed about 1,000-3,000 cercariae per day.

Cercariae are short-lived, surviving not more than 48 hours as a non-feeding organism. Their survival depends on their glycogen reserves, and other factors such as temperature, water turbulence, and water velocity. At high temperatures cercariae move rapidly but soon die. Smyth (1966) reported that when the temperature is 20°C to 24°C, most cercariae exhaust their glycogen reserves in about 8-12 hours. S. mansoni cercariae die after one hour from lack of oxygen, whereas cercariae inside the snail can stand the deprivation of oxygen for 6-16 hours.

When the cercariae find their final host, they attach themselves to the skin by their suckers and shake off their tails. With the assistance of lytic substances from their penetration glands, cercariae pass through the skin of the definitive host. About 15 minutes are needed to pass into the blood vessels under the skin. Then cercariae change in appearance to be schistosomules. They are worm-like, tailless, and unable to live in water, even for a short period.

Wilks (1967) suggested that schistosomules migrate from the lungs to the portal system and may pass directly through the diaphragm to the liver, where they enter blood vessels of the portal system. When worms become sexually mature and have mated, they leave the liver. From the liver they migrate to the veins of the bladder or intestines where they lay eggs and start the cycle again.

The period between the penetration of cercariae and the appearance of eggs in the stools or urine of the definitive host may be 30-40 days.

Gelfand (1967) listed the clinical classification of the stages of schistosomiasis as follows:

1. The stage of invasion: a cercarial dermatitis follows penetration by the cercariae and may be accompanied by systematic symptoms such as fever and weakness. This stage may last for six days. When the schistosomules pass through the lungs they may cause a cough and mucoid or even hemorrhagic symptoms.

2. The stage of completion of maturation and early ovi-position: this stage appears between 15 to 60 days after initial infestation. The main features are fever, headache, anorexia, backache, vomiting, and diarrhea. The liver and spleen may be enlarged and accompanied with anemia.

3. The stage of established infection: this stage is identified by the discharge of ova. The clinical manifestations include diarrhea, dysentery, and abdominal pain, in addition to poor appetite and loss of weight. This stage may last six to twelve months.

4. Stage of irreversible effects: in this stage few or no ova are excreted. The main lesions in this stage result from a fibrotic reaction around them resulting in pathological changes in the tissues of the host. The main organs attacked are the liver, lungs, colon, and bladder. Polypoid growths may develop in the colon and intestinal obstruction may occur.

The Snail Hosts of Schistosomes

The intermediate hosts of schistosomes belong to the class Gastropoda, orders Pulmonata and Prosobranchiata. Two families from the order Pulmonata, namely Planobidae and Lymnaeidae are considered to be the natural snail hosts of Schistosoma.

The family Planorbidae, sub-family Bulininae, contains the intermediate hosts of S. haematobium within the genus Bulinus, including two sub-genera, Physopsis and Bulinus.

The genus Biomphalaria is considered the intermediate host of S. mansoni and is in the sub-family, Planorbinae.

Bulinus

Bulinus snails, the intermediate hosts of S. haematobium, are fresh-water snails, and are identified according to the shape and sculpture of the shell. The shell is sinistral, higher than it is wide, cylindrical, and the snail height is from 4-23 mm, with four or five whorls. The color of the shell varies from white to dark brown. The shell exhibits a sculpture of growth lines. New species form as a result of isolation or variation.

The genus Bulinus is divided into four species: B. africanus, B. truncatus, B. tropicus, and B. forskalii. Bulinus truncatus is found in Libya.

Bulinus africanus (Krauss) is an important species from the medical point of view. It is the intermediate host of S. haematobium in eastern Africa, south of the Sahara.

Bulinus truncatus (Audouin) is found in the eastern and Mediterranean countries of Africa. Members of this species also serve as the intermediate hosts of cattle schistosomes. They are present in western and central Africa.

Bulinus tropicus (Dautzenberg) is distributed in different parts of Africa except for the West. Teasdale (1962) reported that this species serves as an intermediate host of S. bovis, a parasite of some large mammals. There is not enough information to be certain that the members of this species of snail can transmit schistosomiasis.

Bulinus forskalii (Ehrenberg) is widely distributed in Africa. It is also found in the southern region of Yemen. The members of this group act as intermediate hosts for S. haematobium.

Biomphalaria

Biomphalaria snails are the intermediate hosts of Schistosoma mansoni. They are hermaphroditic and do not need to copulate to reproduce because self-fertilization can occur. The snail is a fresh-water snail with a flat discoidal and biconcave shell that has from four to six whorls. The shell is a disc, varying in height, with a diameter between 7 mm to 22 mm. The number of whorls varies according to the species to which the snails belong. When the whorls are few in number, the width is greater. The umbilicus under the center of the whorls may be wide and shallow or narrow and deep.

The snails can survive in the muddy bottom of an empty pond or spring. When the pond refills, a hiding snail can start a new population. The color of the shell is generally brown, white, and, in some cases, reddish. The shell is slightly sculptured with curved, transversely-arranged growth lines.

The genus Biomphalaria is divided into the following species:

Biomphalaria pfeifferi (Krauss) is the most important intermediate host of S. mansoni in the tropical area of Africa. It is small in size, with a shell about 5.5 x 16 mm, consisting of less than five whorls that are angular or convex on both sides. The snail is common in Ethiopia and the Sudan, but is not found in Egypt.

Biomphalaria alexandrina (Ehrenberg) varies in size, but is typically about 4.8 x 14.2 mm. Some show affinities to B. pfeifferi and others to B. sudanica. The snail is common in Egypt and Sudan.

Biomphalaria sudanica (Marteus) is common in the southern Sudan and Ethiopia. It is typically about 4.2 x 15.1 mm in size, although sometimes larger. Their flat shells with a very large umbilicus are distinctive with the umbilicus 1.5 times as large as height of shell.

Sturrock (1966) reported the influence of S. mansoni infection on the growth rate and reproduction of B. pfeifferi. In snails of all ages infection causes a shortened life span with a temporary acceleration in the growth rate proportional to the intensity of infection of individual snails. Snails infected before maturity lay some eggs throughout life but complete sterility results when snails are infected after maturity. Najarian (1961) indicated that S. haematobium in B. truncatus caused a reduction in the egg production.

Charles (1977) indicated that the infection rates of Biomphalaria snails with Schistosoma mansoni are caused by age factors rather than multiple exposure. The infection occurs more frequently in juvenile Biomphalaria snails than in adult Biomphalaria snails (Neuton, 1953).

The intermediate host snails for S. japonicum are placed in three genera, Oncomelania, Schistosomophora, and Katayama. Schistosomophora is different from the others in the number of cusps on the anterior edge, and in the number of whorls in the operculum. The snails in Taiwan and Japan belong to the genus Katayama, in China to Katayama and Oncomelania, and in the Philippines to Schistosomophora. Ansari (1973) indicated that, "it is the consensus that all of the intermediate hosts of S. japonicum (actual or potential) known at present in the endemic area belong to a single genus, Oncomelania."

Ecology of the Intermediate Host

The snail is considered to be an essential link in the schistosome life-cycle. The planorbid and bulinid intermediate hosts are found in a variety of habitats that may include large bodies of water such as lakes, and in small ponds, swamps, marshes, rivers, impoundments, and constructed habitats such as drains and irrigation channels. Many workers have tried to relate the presence or absence of the intermediate host snail to a variety of physical and chemical factors. Webbe (1962) has indicated that snails have the capability of tolerating a wide range of physical and chemical conditions, although it is currently not possible to determine the presence of snail colonization through chemical analysis of its water content.

Measurements of salinity by electrical conductivity have given some valuable results about snail colonization. Harry et al. (1957)

conducted an investigation in Puerto Rico and reported that water containing less than 150 ppm of dissolved solids, with a conductivity of 222 micromhos, did not contain any colonies of Biomphalaria glabrata. They found also an optimal chloride concentration for Biomphalaria snails of 20-110 ppm, and an optimal sulfate concentration of 10-80 ppm (as SO_4). Malek (1958) indicated that Biomphalaria snails can tolerate greater salinity than Bulinus snails. Webbe (1962) observed that in Tanzania no snails were found in water with conductivities of 8-19.7 micromhos/cm at 25°C.

The pH is an important factor for the intermediate host. Acid pH is harmful to mollusks and may cause coagulation of the mucus on the exposed skin surface. Liang (1974) reported that when the pH is more than 7.8, snail reproduction will not occur. He also mentioned that there is no evidence that calcium or magnesium affect the growth rate of snails. This finding contradicts Harrison and Shiff (1966) who reported that a high level of calcium or magnesium can lower the egg-laying potential.

Snails can tolerate the change of temperature although the heart beat and oxygen consumption can be affected by temperature. Chernin (1957) suggested that the oxygen concentration is much more important to the snails than the temperature. van der Schalie and Berry (1973) conducted an experimental study on the effect of temperature on pulmonate snails. They found that when temperature exceeds 30°C, reproduction does not occur since the gonads of snails do not develop. Therefore, the potential of solar energy can be used to increase the temperature of the water to prevent reproduction.

The tolerance of snails to live out of water for months or weeks has important effects with respect to the epidemiology of schistosomiasis. Barbosa and Olivier (1958) reported that immature S. mansoni infections have been found in aestivating snails in the field, and Webbe (1962) has indicated that S. haematobium infection in the snail survived drying for 98 days. The immature infections of both S. haematobium and S. mansoni may be carried in aestivating snails from one season to another. Snails have the ability to survive in dried mud whereas desiccation will kill all ova, young, and adult snails (Chernin and Adler, 1967).

When the water level falls, snails usually burrow into the substratum and become buried in mud at the bases of grass and marginal vegetation on the periphery of the habitat. Snails are stimulated to aestivate before severe changes in the volume of water takes place. When snails are subjected to dessication, Richard (1967) reported that the aquatic snail withdraws the body into the shell and a layer of mucus is produced covering the opening of the shell; apertural lamellae can be formed in aestivating planorbid snails. In the case of bulinid snails that have no operculum, the shell is not sealed under dry conditions.

Schistosomiasis in Libya

Based on the available information from Libya, there are three regions known to be endemic foci for schistosomiasis. Two are for Schistosoma haematobium, the urinary type, namely, in the Derna and Fezzan regions, whereas the Mizurata region is an endemic focus for

Schistosoma mansoni, the intestinal type. In Libya, 168,275 cases of schistosomiasis were recorded in 1972 (Kadiki and Khan, 1972). The earliest cases of schistosomiasis in Derna were recorded in 1955 with a peak of six cases detected in 1963 (Schistosoma haematobium). These cases were suspected to have been imported from Egypt or the Fezzan region, until some were found to be indigenous in nine to 12 year olds who have never left Derna City.

Kadiki and Khan (1972) reported that in 1952 Muller and Feugain were the first to report the presence of Biomphalaria snails in the Taworga region. Godwin (1957) found the infection rate with S. mansoni ova to be 7% in the region.

The involvement of the World Health Organization (WHO) with the problem started in 1963. Various WHO consultants visited Libya and conducted both small scale and extensive surveys. These included Berry, Halawani, and Elgindy. The consultants presented their findings to WHO officials and to the Libyan Health Department. The application of a Bayluscide as a molluscicide in snail-infested water bodies was started for the first time in 1971 in the three endemic foci. Water bodies were treated with a solution of 1 ppm of Bayluscide for 8 hours, but there was no evidence of success in total elimination. Copper sulfate also had been tried without much success, and its effect on the vegetation in the agricultural areas also was a matter of concern.

The Ministry of Health (1975) reported that 33,362 native persons were examined for schistosomiasis in the three endemic regions (Mizurata, Fezzan, and Derna). Of these 3,475 were positive (10.4%).

In addition, 23,460 foreigners were examined for the same disease and the number of infected among them was 2,437 (10.39%).

Schistosomiasis in the Fezzan Region

As indicated, the first cases of Schistosoma haematobium in Ghat were recorded in 1925 as well as the discovery of its intermediate host, Bulinus truncatus. Zavattari (1932) in a general survey of the southern part of Libya, reported on the distribution of Bulinus snails and urinary schistosomiasis. Ladato (1932) reported the presence of Bulinus truncatus and three occurrences of S. haematobium in different parts of the same region. Andolfato and Fedeli (1934) found many cases of S. haematobium in Murzuk. Giardano (1935) reported a case of urinary schistosomiasis in a new region (El Barket) near Ghat. Impallomeni (1937) mentioned the presence of twenty cases of urinary schistosomiasis at Brak and Ubari.

Scaduta (1937) reported the presence of S. haematobium at Murzuk. Casati et al. (1938) were the first to make a general survey. They examined 1,195 persons and found infections in Ubari and Traghen.

Another mass survey was carried out by Nastasi (1938) in the southern region (Sebha, Ubari, Shati, Murzuk, and Ghat). He was the first investigator to find Biomphalaria snails at Ghat and also carried out an extensive survey of Bulinus snails. The occurrence of Biomphalaria raised the problem of the endemicity of rectal schistosomiasis in Ghat. Godwin (1957) reported the presence of urinary schistosomiasis in other regions such as Ashkda, Wenzrik, and Berghin.

Yasuraoka (1966) examined 389 snails (Bulinus) in Sebha City, and found that none of them were infected with the disease. He made a survey in the Shati region and reported that the region was free from Bulinus snails. In this report, the author recommended the use of copper sulfate, 10-30 ppm twice a year as a molluscicide.

Elgindy (1970) reported that 1,864 persons were examined for schistosomiasis. High infection rates were found in Ghat (52%). Twenty-two percent (22%) of the children under five years old who were examined were infected, and the peak of infection (85%) was in the 16-20 year old group. About 30 persons had much blood in their urine samples. Elgindy (1970) indicated that 11,464 persons were surveyed for S. haematobium in the Fezzan region, and 910 (7.9%), based on urine examination, were found to be infected. This survey covered 49 localities including Sebha City. Twenty-five were proven to be endemic foci for S. haematobium. The infected were given Ambilhar chemotherapy. The earliest infection was detected in a three-year-old boy, and the peak infection rates were found in individuals 16-20 years (73%). The infection rate in Traghen Town was 16.5%, in Brak, 18.8%, and in Sebha, 7%. This study shows that the disease was more widely distributed than previously reported.

Snail surveys were carried out in 1980 by WHO team in the Fezzan region. One hundred twenty seven (127) farms were examined and 34 farms were found to be infested, 32 with Bulinus, 1 with Biomphalaria and 1 with both genera in El Barket (Ghat). Of 3,994 snails collected, 50 were Biomphalaria and 3,044 were Bulinus. The infested water bodies were treated with copper sulphate. Two types of Biomphalaria were reported in Ghat, Biomphalaria alexandrina and Biomphalaria pfeifferi.

Egg masses of Bulinus were discovered throughout the year but there was a high mortality rate among them during winter months. Two peak numbers of small snails were recorded, one in autumn and one in spring, the times considered to be the two breeding seasons. Snails infected with S. haematobium cercariae were detected in the month of December and the beginning of June. Infection in snails was not reported in winter or early spring. Schistosoma infections in young snails were found only in late spring or early autumn; infections found in winter or summer were confined to old snails. This probably indicates that infection of snails took place only in spring and autumn.

Amin (1975) reported that of 28,238 people examined in the Fezzan region, 1,761 individuals were infected with S. haematobium. Among them were 188 Libyans, whereas the rest were from Egypt. He concluded that "foreigners constitute a great danger in the increase of the prevalence of the disease."

Schistosomiasis in the Derna Region

The first recorded case of schistosomiasis in Derna was in 1955. After that date, a few cases were diagnosed by the laboratory of the General Hospital in Derna with a peak of six cases being detected in 1963. Berry (1963) indicated that 10 cases of S. haematobium had been reported without giving information about the snail's intermediate host, and these cases were claimed to have spread from Egypt or Fezzan. Hamani (1965) found 20 cases of S. haematobium were recorded for a period of less than 3 months, most of them among children 7 to 16 years of age. These cases were indigenous with no history of the infected individuals having been outside of town. These patients were treated by Fouadin and Stibophen drugs. Hamani (1965) carried out snail searches in several places including Derna City and other towns and found Bulinus truncatus snails in a large quantity only in Ain Dabusia. He emphasized the examination of school children and made suggestions for treatment, health education, and environmental sanitation.

Halawani (1966) investigated the cases that had appeared since 1955 and attributed their origin to cases coming from Fezzan, Egypt, or from other neighboring endemic foci. He examined 106 school children, with ages ranging from 6 to 9 years and found 9 positive, a rate of 8.5%. In another sample from students with ages ranging from 10 to 14, 7 infected cases were found among 106, a rate of 6.4%.

Elgindy (1970) reported that, in the past, Ain Dabusia was highly infested with Bulinus. At the present time all water coming out of the spring is pumped through pipes with the nearby region completely dry without a trace of Bulinus snails. Ain El Belad is a large spring in Derna, but Elgindy (1970) reported the presence of Bulinus truncatus in this spring.

A unit for bilharziasis control was established in 1971 to undertake epidemiological as well as malacological surveys in Derna City, the last location found as an endemic foci for urinary schistosomiasis. This unit was established under the supervision of WHO. This unit is now staffed by the Libyan Health Department with a medical doctor, health inspector, and a nurse. The WHO

(1971) reported a survey conducted in Derna of 7,228 students, in which 285 were found to be infected with S. haematobium, for a rate of 3.9%. Boys had a higher infection rate of 4.4% as compared with a rate of 3.3% for girls. The infection was detected in children as young as 6 years, although most cases were for children between the ages of 6 and 17. Most of these students were born in Derna City, whereas the others were born in towns near the city, or in endemic areas in neighboring countries such as Egypt, Sudan, and Tunisia. The majority of individuals infected were within the ages of 6 to 17 with few contracting the disease in Egypt. The report (WHO, 1971) indicated that a snail survey was conducted and Bulinus truncatus snails were found but details were lacking.

Schistosomiasis in the Mizurata Region

Taworga is a well known focus of Schistosoma mansoni. The focus is limited to Taworga Town North to El Heesha south, 60 kilometers away. Most of the region is watered by a main spring. People wash their clothes, swim and children play in the water. Godwin (1957) conducted a survey of S. mansoni near the spring. He found that 60% of 126 stool samples from students were positive. Yasuraoka (1966) reported the presence of Bulinus alexandrina, but the report probably contains a typographical error and should be Biomphalaria instead of Bulinus. He indicated that in a survey conducted on that type of snail, out of 413 snails, he found only 1 infected with S. mansoni. He also found a large quantity of shells around the spring.

Godwin (1957) indicated that El Heesha is an endemic focus for S. mansoni according to a positive skin test for 19 persons in the El Heesha region. Elgindy (1970) was the first to report the presence of Biomphalaria in El Heesha and indicated that 97 persons were examined for S. mansoni in the El Heesha region with negative results.

Engindy (1970) reported that the WHO team made a survey, based on stool samples, of 1,283 persons in the Taworga region and El Heesha for S. mansoni. Out of the samples, 243 were infected, for a rate of 18.0%. However, persons from the El Heesha region appeared to be free of the infection. He reported also that the infection rate among students in the nearest school to Taworga spring is high, 86%. The highest infection rate was in children less than 11 years of age. There is strong evidence that the spring is the source of infection, since the closer the children live to the spring, the higher is the rate of infection.

Elgindy (1970) indicated that 55 streams in the Taworga and El Heesha regions were surveyed and 34 were found infected. The number of snails collected were 2,760 and an unspecified number of schistosome cercariae were detected.

Treatment of schistosomiasis with Ambilhar was introduced for the first time in Libya in 1970 following the recommendation of the WHO. The classical amount of 25 Mg/kg/body weight daily in 2 doses for 7 days is used.

The WHO (1971) reported that stool samples of 813 persons were examined in the Taworga region for S. mansoni infection. Fourteen were found positive, for an infection rate of 16.8%. Schools of the

Taworga region were surveyed the same year, and of 1,578 students, 246 were positive with respect to infection, for a rate of 15.5%. WHO conducted another survey by collecting stools from the tribes around the spring, examing 728 persons with 266 having active S. mansoni infection, for a rate of 36.5%. All the positive cases were given Ambilhar drug as a treatment.

The WHO (1971) reported that 2,391 urine samples were collected in the Mizurata region from students in 10 schools and only 1 Egyptian student was found to be infected with urinary schistosomiasis. Amin (1975) visited the Mizurata region and reported that 778 Biomphalaria snails were collected and none were infected. He also indicated that the water contact activities in the spring, such as swimming and washing, were great and the shores were highly polluted with fecal matter. Consequently, he recommended building a fence around Taworga spring to prevent personal contact. Amin (1975) indicated that foreign employees of the agricultural projects constitute a great danger in terms of spreading the disease. He reported that of 668 persons examined (mainly Egyptians), 502 were found to be infected, for a rate of 75.1%.

Swehli (1979) investigated the infection rate in the Mizurata region and found that it was 22% among the total population and 86.5% among students. The intermediate host, Biomphalaria, showed an infection rate of 1.3%.

Schistosomiasis in Neighboring Countries

Schistosomiasis in Tunis

The only type of schistosomiasis reported in Tunis is *Schistosoma haematobium* in different endemic regions such as Gafsa and Sidi Mansour. Vermeil (1957) observed that the infection rate in Gafsa city was 69% among boys and 16% among girls. Combaras (1960) reported, according to his survey in the Kelbi region (southern part of the country), that 572 students were found to be positive among 919, for a rate of 62%. The lowest rate was in the 6 year old group (22%) and the highest was among 13-14 year olds (64%). Combaras (1961) made another survey and found other endemic regions in El jerid, Zarat, El hama, and Matmata. Azar (1968) reported an infection rate of 21% in Kebli. He also reported that Gafsa town was infected with *S. haematobium*, with high rates in Lalla, El-Kasr, and Gafsa Nord.

The intermediate host of *S. haematobium* in Tunis, *Bulinus truncatus*, is found in the irrigation canals and around the artesian wells.

Schistosomiasis in Algeria

Schistosoma haematobium is the only type of schistosomiasis reported in Algeria. The endemic foci are in the northern part of the country in Foundouk, St. Aimé de la Djidioua and Biskra, and in Djanet, located in the southern part of the country near the Libyan border. Deschiens (1952) reported that in St. Aimé de la Djidioua, the infection rate was 42.7%, whereas in the oasis of Djanet the rate was 85%.

The intermediate host of S. haematobium in Algeria, Bulinus truncatus, was found in all the above regions. Planorbarius metidjensis snails have been reported in Foundouk and other endemic foci.

Schistosomiasis in Niger

Schistosoma haematobium has been reported in different parts of Niger. Gaud (1955) reported that the prevalence rate in Ziner was 60% and in Tanout, 33%. There are other foci at Naimey, Birni-N'Konni and Tillabery, the prevalence rate being 44.6% based on the evidence from examining 13,856 persons for S. haematobium. In Magaria, the infection rate was 21.12%. Along the River Niger, the highest infection rate recorded for a population was 44.6%.

The intermediate hosts, Bulinus spp., were reported in different regions such as Zinder, Maratli, and Dungas.

Schistosomiasis in Chad

Both types of Schistosomiasis, S. mansoni and S. haematobium, have been reported in Chad. The important endemic foci are reported to be around Lake Chad. In the northeastern section of Chad, urinary and intestinal schistosomiasis have been reported in Abecha. Guyon (1965) reported that S. mansoni occurs in the north, whereas S. haematobium is found in the south. The infection rate of S. haematobium in different regions ranged from 16 to 87%.

In Faya-largeau, located in the northern part of the country near the Libyan border, the infection rate was S. haematobium was 77.5%.

Ansari (1973) reported that Watson conducted a survey in 1970 and found that 3% of the population of Chad was infected with urinary schistosomiasis. Buck et al. (1968) made a survey in areas of the northern and southern parts of Chad and found infection rates of 16.4% for S. haematobium and 15.2% for S. mansoni.

Bulinus truncatus has been reported in several regions in Chad along with Biomphalaria sundanica and Biomphalaria pfeifferi.

Schistosomiasis in Sudan

Urinary and intestinal schistosomiasis are endemic in Sudan. McMullen and Buzo (1959) indicated that about 554,000 persons were infected with Schistosoma mansoni and about 830,000 with Schistosoma haematobium. S. haematobium has been found in the central part of Sudan from the Ethiopian border in the east to Darfur province in the west. Above this region, schistosomiasis follows the Nile River up to the border of Egypt. Farooq (1961) reported that the highest infection rates were along the Blue Nile and in the Kordofan province.

South of Khartoum along the Blue Nile in the Gezira region, the infection rate decreased during the years 1951-1960, from 4.1 to 1.0% in children, whereas S. haematobium infection increased in the new irrigation areas in the Khartoum province. The highest endemic in Sudan is in Darfur province with a prevalence rate of S. haematobium of 90% (Watson and Lindquist, 1967).

In Sudan, Schistosoma mansoni infection rates are not so high as infection rates for S. haematobium. El Amin (1970) indicated that a severe type of S. mansoni has been reported in the upper Nile province.

The greatest infection with S. mansoni occurs along the White Nile with an infection rate between 60 and 90%.

In Sudan, B. truncatus, B. globosus, and B. forskalii are the snail hosts for S. haematobium, whereas B. pfeifferi and B. sudanica are the snail hosts for S. mansoni. B. truncatus is found in the north and in the central part of Sudan, whereas B. pfeifferi and B. sundanica are found in the Blue and White Nile provinces.

Schistosomiasis in Egypt

Schistosomiasis heads the list of endemic diseases in Egypt. Scott (1937) made a survey in various villages in which he examined about 40,000 persons in different localities. He found a prevalence rate of 32% for S. mansoni in the Nile Delta.

In 1955, the Ministry of Public Health made a general survey involving 124,253 randomly selected persons. The prevalence rate was found to be 9% for S. mansoni in the Nile Delta and 38% for S. haematobium in the rest of the country. They found that the prevalence rate rose in the southern part of the country, in Suhag, from 3% in 1935 to 42% in 1955. The rise in rate is attributable to the change from basin or flood irrigation, that happens only during the flood of the Nile, into perennial or all-year-round irrigation. Continuous irrigation provides more opportunity for the propagation of infection. This indicates that the irrigation system has a great impact on the spread of human schistosomiasis in Egypt. The prevalence rate of schistosomiais is higher in males than in females and rises with age, reaching a maximum rate in hosts between the ages of 10 to 15 years (Satti, 1970).

According to reports from the endemic diseases hospitals during 1965, the number of people examined was 1,252,258. The infection rate for S. haematobium was 37.0% and for S. mansoni 4.3%.

Bulinus truncatus is the intermediate host of S. haematobium that is found throughout the country in the main canals and in the Nile and its branches, especially where vegetation exists or residual pools are left when the water recedes.

Biomphalaria alexandrina, the snail intermediate host of S. mansoni is common in lower Egypt, especially in the northern part of the Nile Delta. Snails usually are more abundant in drains than in irrigation channels.

Mansour et al. (1981) conducted a study in upper Egypt. They found that, on the basis of urine examination, the overall rate of infection for S. haematobium was 28.7%. They reported also that S. haematobium infection occurred in all age groups including infants below 1 year of age. Children in the 11 to 15 age group had a rate of infection of 57-63%, although the infection rate declined to 28% in adult years. They indicated also that males, at all ages, had higher infection rates than did females.

King et al. (1982) made a survey in upper Egypt for S. haematobium using the nucleopore membrane filtration technique of a single urine specimen. They found a prevalence rate of 37%. They also found 9 from a total of 4,312 Bulinus snails were infected with schistosomes, for a rate of 0.21%. No Biomphalaria snails were found in the region.

CHAPTER III

MATERIALS AND METHODS

The method used in this study is descriptive rather than experimental. Snail specimens were collected in the 3 regions listed in Table 2 making it possible to gather comparative data that might be useful for controlling schistosomiasis. Specimens were gathered and examined for relevant data in the springs and summers of 1980 and 1981.

Description of the Regions in Libya With Endemic Schistosomiasis

In Libya there are 3 endemic foci of schistosomiasis. Two of them, the Derna and Fezzan regions, have _Schistosoma haematobium_ and the third region, Mizurata, has _Schistosoma mansoni_.

Table 2
Areas and Populations of the Study Locations

City or District	Area Km^2	Population 1973 Census
Derna	12,680	44,145
Mizurata	33,270	102,439
Fezzan		
Shati (Brak)	97,160	27,183
Ubari	31,890	19,132
Murzuk	349,790	22,185

Source: Libya. Ministry of planning. 1978. _The national atlas for Socialist people Libyan Arab Jamahyria_. Stockholm: Isleet Co., p. 26.

The Derna Region

Derna is situated in the eastern part of the Green Mountains (Jabel El-Akhdar), 250 km east of Benghazi. It has an area of 12,680 m^2 that stretches from the narrow coastal strip, up over the escarpment to the hills and plateau, and then descends into the desert. The city has a Mediterranean climate, but during the winter, the temperature may fall to 4°C with a winter rainfall average of 500 mm. Derna River is dry most of the time and receives water only during rainy seasons. The El-Fatayeh Agriculture Project is located in Wadi Derna, and covers 5,000 hectares.

According to the census of 1964, the city had a population of 23,713 persons, but the number increased to 44,145 by 1973.

Derna is largely agricultural and gets its water from two springs. Ain Derna, sometimes called Ain El-belad, is located 3 kilometers south of Derna City.

Ain Derna is a covered spring from which 2 pumps lift water into 2 large tubes that provide Derna with potable water. The water discharge of this spring is about 125,000 gallons per day, but this quantity decreased recently and a shortage resulted. To compensate for the shortage, additional water was provided from a water desalination station located in Derna. From Ain Derna, water runs in an open stream at the bottom of the valley, where as dam is located. Water enters a covered cement channel and divides into Maghar and Gebeila irrigation streams.

Ain Abu Mansour provides irrigation water to the agricultural area. Springs are found along the stream that is about 5 km long.

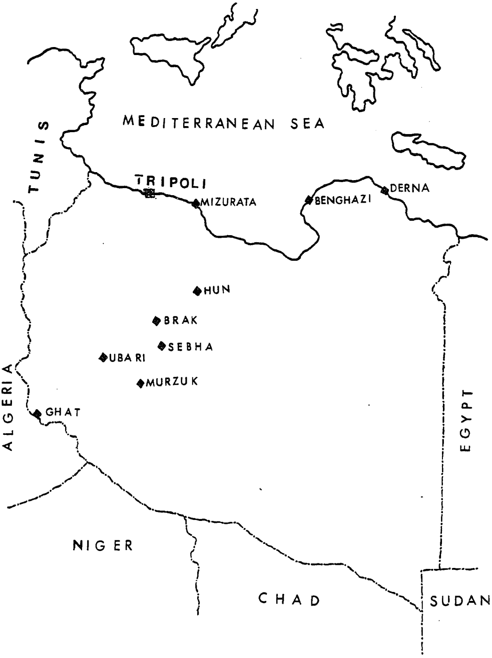

Fig. 6. Map of Libya showing the principle cities of the study regions.

Most of the data for the Derna region were obtained from Ain Mara. This spring is formed from two other springs, Ain Shaib and Ain Safa.

The Fezzan Region

The southern region (Fezzan) is a desert with an area of 640,140 km^2. Groundwater is the main source of water since there is practically no rain. Water is raised by mechanical pumps or provided by artesian wells. Agricultural activity is limited almost completely to the cultivation of palm trees, barley, wheat, and a few vegetables. There are several recently-established agricultural projects in the region (Table 3) that depend completely on the groundwater. Domestic animals include camels, sheep, donkeys, and goats. Temperatures during the winter season range from 10°C to 5°C, whereas during the summer season temperatures range from 32°C to 45°C.

Table 3
Agricultural Projects in the Fezzan Region

Name of the project	Area of project in Hectares
Wadi Shati (1)	4355
Wadi Shati (2)	3900
Shebha	1300
Murzuk	5270
Cereal for Fezzan area	12400
Wadi El-hayat	8160
Ghat	325

Source: Libya. Ministry of planning. 1978. The national atlas for Socialist people Libyan Arab Jamahyria. Stockholm: Isleet Co., p. 65.

The region is divided into 5 districts: Sebha, Ubari, Shati, Murzuk, and Ghat. These districts are connected by roads that facilitate transportation between the cities. Most of the people are farmers, who depend on groundwater to irrigate their crops. Water is pumped using electrical pumps and collected in a large storage tank (Jabia) about 6 meters in diameter and 3 meters in depth. Water goes through cemented canals for irrigation. Some farmers do not use Jabia but instead use piped irrigation systems instead of cemented canals. *Bulinus* snails are located in the water storage tanks and in the small irrigation canals.

The Mizurata Region

Taworga, a well known focus of *S. mansoni*, is 250 km east of Tripoli and 50 km south of Mizurata City and is reached by following the highway to Benghazi for 35 km and turning west for 15 km. Taworga town has a population of about 20,000 persons. The focus of the infected area appears to be Ain Taworga because of the presence of *Biomphalaria* snails that are the intermediate host of *S. mansoni*. Ain Taworga is an old spring and the largest in Libya with a perimeter of 700 meters. It has an average discharge of 3.5 cubic meters (m^3) per second with warm water all year around. One main river and a few small canals originate at Ain Taworga. The main river is divided into several streams supplying many villages with water, and the streams have many branches that end in a vast area of marshes.

Palm trees and *Juncus* plant (Dees) grow extensively and contribute a major share to the economy. *Juncus* grows along most of the irrigated wet land. Adults collect the Juncus plants and the women process them into mats and other hand-crafted articles. Domestic animals include sheep, goats, cows, chickens, and donkeys. These animals may act as reservoir hosts for schistosomiasis.

The Taworga agricultural project is a land reclamation project in which the water of the spring is transferred 15 kilometers to the west side of the highway where it irrigates a 3,000 hectare area occupied by 5,000 persons on 150 farms. About 50% of the water is excess water used to flush salts from the agricultural project. This water is then diverted to irrigate the old area for the growth of the Juncus plant. This agricultural project started in the early 1970's and was developed by an Egyptian land reclamation company (El-bahaira). Most of the farmers in the labor force are from Egypt.

Ain Taworga forms from two internal springs near each other that merge into the big one that carries the name. The deepest part of the spring is said to vary from 300 to 400 meters, and the temperature ranges from 25°C to 27°C. People living around the spring take their water supply directly from the small streams that originate at the spring. Most of the streams are heavily populated with Biomphalaria snails. Children and women living close to the spring have much contact with the water as a result of washing dishes, washing clothes, swimming, and using the water for other domestic purposes. Many tribes live in the Taworga region. Most of them are settled tribes, although some tribes are nomadic and live in tents and move from one place to another with their animals, collecting the Juncus plants.

The El heesha Region

A second location investigated in this study was El heesha in the Mizurata Region. It is a marshy land with about 800 inhabitants. El heesha is reached by following the highway from Mizurata to Benghazi for 95 km and then turning east for about 14 km on a coarse road. There are several springs in the region, some with soft water and others with salty (brackish) water. The inhabitants of this region use the salt water from the springs for washing and the soft water from other springs for drinking and other activities. Many of these people migrated from other parts of the Mizurata region to this location to cultivate the Juncus plant. The migration of these people from one place to another can transmit the Biomphalaria snails. There is a project to settle these people in one place by giving them free houses with potable water available. This would give them less contact with the parasite. The main feature that characterizes both locations (Taworga and El heesha) is the marshy nature of the oases and the salty soil.

Snail Collecting Technique

Snails detected visually were collected with forceps in shallow water or under rocks. In most cases, however, aquatic dip nets were used to collect snails in large numbers. A boat was used in Taworga spring for access to the inlet of the spring, but in most of the places, snails were found beneath the surface film or along the sides of the water tanks and irrigation canals, as was the case in the Fezzan region. All snails in the net or on the objects examined were collected and were put in separate containers to identify where they were collected. Small amounts of water were added to transport them live to the laboratory for examination and identifcation.

Derna

Ain Mara was chosen for this study. Three hours were spent collecting all types of snails in each of the springs using forceps because of shallow waters.

Mizurata

A large number of snails were collected from the Taworga spring in Mizurata. Snails along the edge of the spring were collected with forceps. In El heesha in Mizurata, snails were collected from the springs, Ain Zayed, Ain Hassan, and Ain El Jemal. The snails were in heavily vegetated locations and were found beneath the algal surface film of the spring. About one hour was spent collecting in each spring.

Fezzan

In Fezzan, farms were visited in each of the oases of Brak, Murzuk, Ubari, and Sebha. Snails were collected in the water bodies that are mainly water tanks (Jabia) and cemented irrigation canals.

Examination of Snails for Schistosome Infection

After arrival at the laboratory, the snails were washed, separated according to species, and their numbers were recorded.

Biomphalaria and Bulinus snails were separated according to where they were collected and were then put in widemouthed covered containers and were fed with fish food. The water was checked twice a day for three days for emerging cercariae. The water was poured off and examined under low magnification.

The snails were examined to determine whether or not they had schistosome infections. They were placed in petri dishes and their shells were crushed. Two drops of water were added to each crushed snail, the broken shells were removed with dissecting needles under a dissecting microscope, and a search for the presence of additional cercariae was made in the macerated bodies.

Physical and Chemical Observation

Five measurements were made for each of the characteristics of temperature, pH, dissolved oxygen, conductivity, and turbidity, for a total of 25 measurements. Most of these measurements were conducted near the surface of the water. Air temperatures were recorded for each location. Water temperatures were measured with a laboratory type mercury thermometer. A portable pH meter was used to measure pH.

For chemical analysis, approximately 4 liters of water were taken from different surface locations. These were then taken to the nearest central laboratory for determining Ca^{++}, Mg^{++}, Na^{++}, K^{+}, Cl^{-},

F^-, $SO_4^=$, $NO_3^=$, total hardness and alkalinity, using standard chemical methods.

Epidemiological Study

Stool and urine samples were collected and examined for eggs to study the infection rate of schistosomiasis. A total of 439 adult patients who visited the medical clinic in the three endemic regions during this investigation were asked to submit stool and urine samples. Among these subjects, from the Derna region where the population is about 44,145 persons, 47 adults were examined, representing 0.1% of the total population. In Sebha region where the population is about 35,879, 96 adults were examined, representing 0.26% of the total population. In Taworga region, where the population is about 20,000, 192 persons were examined, representing about 1% of the total population. Among the others examined were 83 students, 15 years of age or under, from a total population of 1,099 students. These represented 7.5% of total student population in the region. Because this investigation was carried out during the summer and most of the schools are closed, it was not possible to get samples from students except in the Taworga region where one school was open for religious studies. There is no way of knowing to what extent those examined were representative of the total population. However, all those who agreed to submit urine and stool samples were used as subjects.

Examination of Stool for Ova

Every person was given a 40 ml labeled container (disposable) with a lid and was instructed to place about 10 cm^3 of his freshly passed stool in the container. These samples were stored in a refrigerator and examined within 24 hours. Samples were handled using two methods, direct smear and sedimentation. If ova were found in the first test, sedimentation was not necessary, but if there were negative findings, then the sedimentation technique was applied on the same sample.

Direct Smear

Two drops of saline solution were dropped in the center of a slide. A piece of the fecal sample was stirred into that solution and was covered with a cover-slip and examined for *Schistosoma mansoni* eggs under the microscope at 100X and 430X.

Sedimentation

A small piece of the fecal sample (about 1 gram) was placed in a breaker containing 2 ml of normal saline solution as a dilutant. This was beaten until the stool sample was broken into small particles and then poured through a sieve while stirring. It was then funneled into a test tube with more saline solution being added if necessary. The contents of the test tube were allowed to settle for about 30 minutes and the supernatant was then decanted. The sediment was poured into a petri dish, and the tube was washed with saline solution that was poured into the petri dish. The mixture was then allowed to settle for about five minutes and was examined under a binocular microscope.

Examination of the Urine for Ova

Urine samples were collected in labeled screw-top disposable urine collectors provided by the Ministry of Health. After the collection has been completed, the samples were transferred to test tubes and centrifuged for about one minute with a hand centrifuge. This technique concentrates the ova of S. haematobium in the bottom of the test tube. A small drop of this residue was then placed on a clean glass slide and examined under the microscope at 100X and 430X.

Statistical Analysis

Statistical tests reported in the results were undertaken using the Statpack Program available on Western Michigan University's DEC-10 computer. Percentages and means were calculated. Tables and graphic displays of the raw data were also prepared and appear in the results.

CHAPTER IV

RESULTS

Distribution of the Intermediate Host Snails

The intermediate hosts of schistosomes were found in the three endemic regions, Mizurata, Derna, and Fezzan. In Mizurata, 2,559 snails (Table 4) were collected from Ain Taworga, Ain Hassan, Ain Zayed, and Ain El jemal; 1,742 snails, or 68%, were *Biomphalaria alexandrina*. Among the snails collected were *Melanoides tuberculata* and *Physa acuta*, in the amounts of 22.4% and 9.59% respectively (Table 8).

In the Fezzan region, 68 farms were examined for *Bulinus truncatus* snails. The snails were found in the irrigation system of 14 farms (Table 5). The total number of snails collected in the region were 968 (Table 6); of those, 907 snails, or 93.7%, were *Bulinus truncatus*. The only species accompanying the intermediate host was *Lymnaea*, in the amount of 6.3%.

In the Derna region, 6 different types of snails were found (Table 7), including *Bulinus truncatus* that was the dominant species. The total number of snails collected was 202. The largest numbers of snails were *Bulinus truncatus* and *Gyralus ehrenbergi*, in the amount of 37.1% and 30.7% respectively. The rest of the snails belong to *Pseudamnicola dupotetiana*, *Lymnaea* sp, *Bythinia* sp, and *Succinia* sp, in the amount of 12%, 29%, 16%, and 8% respectively (Table 7).

Table 4
Snails Collected from Mizurata Springs

Name of Spring	*Biomphalaria alexandrina*	*Melanoides tuberculata*	*Physa acuta*	Total of all species
Ain Taworga	894	157	82	1133
Ain Hassan	250	105	5	360
Ain Zayed	480	243	135	858
Ain El jemal	118	69	21	208
TOTAL	1742	574	243	2559

Table 5
Irrigation Systems Infected with Bulinus Snails in the Fezzan Region

Name of the region	No. of farms examined	No. of systems infected	% infected
Sehba	20	3	15
Shati	13	1	7.69
Murzuk	19	8	42.1
Ubari	16	2	12.5
TOTAL	68	14	20.58

Table 6
Snails Collected from the Fezzan Region

Name of the region	*Bulinus truncatus*	*Lymnaea* sp.	Total of both species
Sebha	374	17	391
Shati	18	--	18
Murzuk	432	42	474
Ubari	83	2	85
TOTAL	907	61	968

Table 8
Snails Collected in the Study Regions

Region and total number of snails collected	Species of snails	Number collected	% Collected in the region
Mizurata	Biomphalaria alexandrina	1742	68
(2559)	Melanoide tuberculata	574	22.4
	Physa acuta	243	9.5
Fezzan	Bulinus truncatus	907	93.7
(968)	Lymnaea sp.	601	6.3
Derna	Bulinus truncatus	75	37.13
(202)	Gyralus ehrenbergi	62	30.7
	Pseudamnicola dupotetiana	12	5.9
	Lymnaea sp.	29	14.36
	Bythnia sp.	16	7.0
	Succinia sp.	8	4.0

Table 7
Snails Collected from the Derna Region (Ain Mara)

Name of Snails	Number of Snails
_Bulinus truncatus_*	75
Gyraulus ehrenbergi	62
Pseudamnicola dupotetiana	12
Lymnaea sp.	29
Bythinia sp.	16
Succinia sp.	8
TOTAL	202

*None were infected with schistosomiasis cercaria.

Many reddish-brown leeches of the type _Hirudo medicinalis_ were found in the water. The inhabitants indicated that these leeches became attached to the throats of their sheep and cattle and cause inflammation.

Incidence of Cercaria in Snails

The regions most heavily infested with _Biomphalaria_ snails in Mizurata (Taworga and El heesha) were Ain Taworga, Ain Hassan, Ain Zayed, and Ain El jemal. The highest infection rate in the region was found in Ain Taworga at 0.89%. The 894 _Biomphalaria_ snails from the spring were separated into 15 containers with about 60 snails in each, and these were checked twice a day for cercariae. The cercariae appeared in only 3 containers. Each _Biomphalaria_ snail was crushed and 8 eight were found to be infected, in the amount of 0.89% (Table 9).

Two hundred fifty _Biomphalaria_ snails from Ain Hassan were divided into five containers. The cercariae appeared only in 1 container. But when the snails were crushed, 2 were found to be infected, for a rate of 0.8% (Table 9).

A total of 480 snails were collected from Ain Zayed and divided into 10 containers with 48 snails in each. No cercariae appeared in the surface, but when the snails were crushed, 1 was found to be infected, a rate of 0.2% (Table 9).

A total of 118 _Biomphalaria_ snails from Ain El jemal were divided into 4 containers with 30 or 28 snails per container. Cercaria did not appear at the surface in any of these. When the snails were crushed, none were found to be infected.

In the Fezzan region, a total of 907 _Bulinus_ snails were examined for cercaria and 4 were found to be infected, for a rate of 0.44% (Table 10).

A total of 374 snails collected from 3 farms in the Sebha region were divided into 8 containers with about 47 snails per container. Cercaria appeared at the surface in only 1 container. When the snails were crushed, 3 were found to be infected, for a rate of 0.8% (Table 10).

Eighteen snails were collected from 1 farm in the Shati region and then placed into 1 container. Cercaria did not appear at the surface and when the snails were crushed, none were found to be infected.

A total of 432 _Bulinus_ snails collected from 8 farms in the Murzuk region were divided into 10 containers with about 43 per container. An examination failed to show presence of cercaria at the

Table 9
The Infection of _Biomphalaria_ Snails with Schistosomal Cercaria in the Mizurata Region

Name of spring	No. of snails examined	No. of snails infected	% infected
Ain Taworga	894	8	0.89
Ain Hassan	250	2	0.8
Ain Zayed	480	1	0.2
Ain El jemal	118	0	0
TOTAL	1742	11	0.63

Table 10
The Infection of _Bulinus_ Snails with Schistosomal Cercaria in the Fezzan Region

Name of Region	No. of snails collected	No. of snails infected	% infected
Sebha	374	3	0.8
Shati	18	0	0
Murzuk	432	1	0.23
Ubari	83	0	0
TOTAL	907	4	0.44

surface. When the snails were crushed only one was found to be infected, for a rate of 0.23% (Table 10).

Eighty-three Bulinus snails were collected from 2 farms in the Ubari area and placed in 2 containers, with 41 and 42 in the respective container. Cercaria did not appear at the surface, and when the snails were crushed, none were found to be infected (Table 10).

Seventy-five Bulinus snails were collected from Ain Mara and divided into 5 containers, with 15 snails in each. Cercaria did not appear at the surface, and when the snails were crushed, none were found to be infected (Table 7).

Water Chemistry

From the measurements of physical characteristics reported in Tables 11, 12, and 13, the highest air temperature recorded during this study was 42°C in the Taworga region (Mizurata) and the lowest temperature was 28.2°C in the Derna region. Water temperatures ranged

Table 11
Physical Characteristics of Water in the Derna Region (Ain Mara)

Air temperature (°C)	28.2
Water temperature (°C)	24.4 - 26.0
pH	6.9 - 7.4
Turbidity (ftu)	6.2 - 8.5
Dissolved oxygen in water (ppm)	8 - 14
Conductivity (umhos)	515 - 600

Table 12
Physical Characteristics of Springs in the Mizurata Region

Physical Characteristic	Ain Taworga	Ain Hassan	Ain Zayed	Ain El jemal
Air temperature °C	42	36	36	36
Water temperature °C	28.1 - 28.7	26.5 - 27.9	26.5 - 27.8	26.6 - 28.1
pH	7.2 - 7.6	7.3 - 7.8	7.4 - 7.7	7.2 - 7.6
Turbidity (Ftu)	80 - 86	22 - 40	87 - 110	40 - 68
Dissolved oxygen in water (ppm)	8 - 15	8 - 15	9 - 14	9 - 14
Conductivity (umhos)	500 - 570	560 - 610	550 - 810	540 - 600

Table 13
Physical Characteristics of the Well-water in the Fezzan Region

Physical Characteristic	Sebha	Shati	Murzuk	Ubari
Air temperature °C	38	36	40	38.5
Water temperature °C	24.2 - 26.0	25.9 - 27.6	24.0 - 26.4	25.6 - 27.2
pH	7.2 - 7.8	6.9 - 7.4	7.3 - 7.3	7.2 - 7.6
Turbidity (ftu)	32 - 42	35 - 48	27 - 36	40 - 62
Dissolved oxygen in water (ppm)	9 - 16	8.5 - 14	9 - 16	9 - 18
Conductivity (umhos)	560 - 690	530 - 610	490 - 570	540 - 630

from 24°C in the Murzuk region (Fezzan) to 28.7°C in the Taworga region (Mizurata). According to the pH results, there are similarities in most locations with a pH range of 6.9 to 7.8. The highest turbidity was in Ain Zayed (Mizurata). All the waters tested had adequate amounts of oxygen. Dissolved oxygen ranged from 8 to 18 (ppm).

Inspection of the water analyses to compare data for the three regions (Table 14) showed relatively similar values for dissolved material. There is no evidence to judge whether the differences noted are sufficient to limit the distribution of schistosomes.

Table 14
Water Analyses of Samples for Sebha Region, Fezzan; Ain Mara, Derna; and Ain Taworga, Mizurata
All values are in mg per liter

Ion	Sebha Region	Ain Mara	Ain Taworga
Magnesium	12.3	7.6	8.3
Calcium	16.1	20.2	14.9
Sodium	19.7	25.3	21.2
Potassium	2.8	1.95	1.2
Bicarbonate	7.1	6.2	5.9
Chloride	20.6	22.8	29.8
Nitrate	1.2	0.3	0.49
Sulphate	9.8	12.8	11.2
Silica	---	19.5	17.0

Incidence of Human Infection

Measurement of human infection was made during the summer of 1981, by stool and urine examination depending on the type of disease indigenous to the region. Samples were taken in the morning and examined with 24 hours (Fig. 7).

In the Mizurata region, samples were collected from the nearest school to Ain Taworga (Sayeda Aisha Religious School). The school was situated 250 meters away, on the south side of the spring. Students play in the spring that is heavily populated with Biomphalaria alexandrina snails. Eighty-three students were examined. All of the 10 year olds were infected. Infection was not found in the 7 year olds, whereas a high infection rate with S. mansoni (over 83.3%) was found in students between the ages of 10 and 14. The overall infection rate among children of all ages was 65.0% (Table 15, Fig. 8).

The relationship of age to infection rate was significant at the 5% level based on analysis of variance. Stool samples were collected from adult population in the Taworga area and analyzed. The highest infection rate was found in the 20 to 29 (38.8%) year old group. The overall infection rate for the adult population of all ages was 18.34% for S. mansoni (Table 16, Fig. 9). There was a highly significant relationship between age and the percent infected (0.005 level).

Urine examinations were conducted in the Derna region (Table 17, Fig. 10) to check S. haematobium infection rates of the adult male population. The highest infection rate was 22.2% for those between the ages 30 and 39. No infection was found in the age groups 20 to

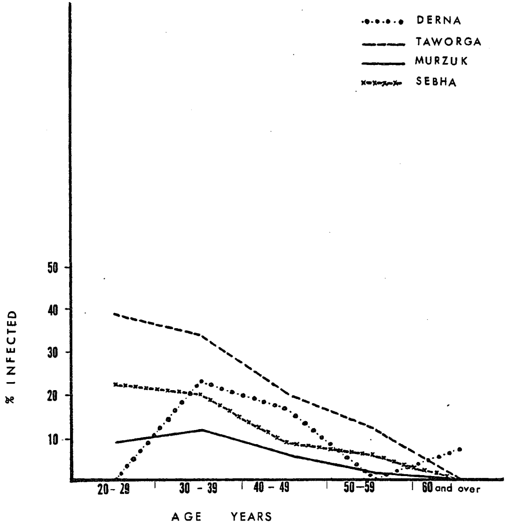

Fig. 7. Schistosomiasis infection rates in the study areas.

Table 15
The Infection Rate of *S. mansoni* in Students
in the Taworga Region Based on Stool Examinations

Age	No. tested	No. positive	% infected
6	2	1	50
7	4	0	0
8	5	2	40
9	8	4	50
10	5	5	100
11	10	9	90
12	15	13	86.6
13	12	10	83.3
14	10	9	90
15	12	9	75
TOTAL	83	54	65.0

Table 16
The Infection Rate of *S. mansoni* in the Adult Male
in the Taworga Region Based on Stool Examinations

Age	No. tested	No. positive	% infected
20-29	18	7	38.8
30-39	12	4	33.3
40-49	31	6	19.35
50-59	26	3	11.53
60 & over	22	0	0,0
TOTAL	109	20	18.34

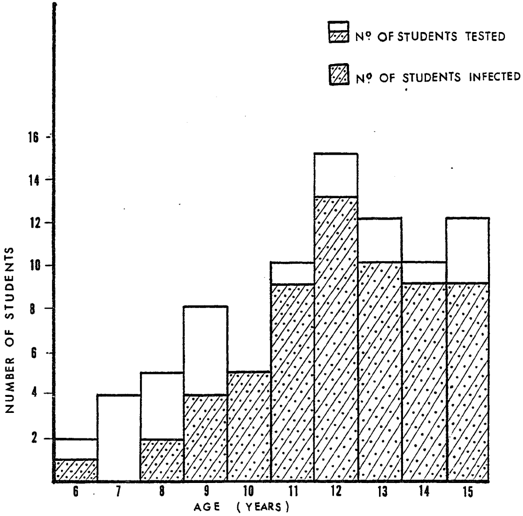

Fig. 8. A histogram of S. mansoni among students surveyed in the Taworga region.

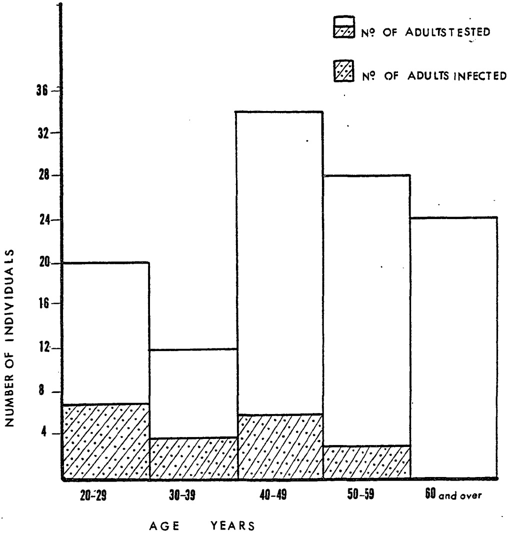

Fig. 9. A histogram of S. mansoni among adults surveyed in the Taworga region.

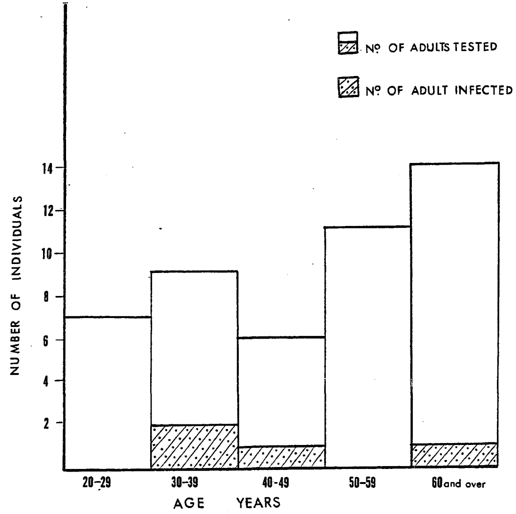

Fig. 10. A histogram of S. haematobium among adult males surveyed in the Derna region.

Table 17
The Infection Rate of S. haematobium in the Adult Male Population in the Derna Region Based on Urine Examination

Age	No. tested	No. positive	% infected
20-29	7	0	0
30-39	9	2	22.2
40-49	6	1	16.6
50-59	11	0	0
60 & over	14	1	7.14
TOTAL	47	4	8.5

29 or 50 to 59. The overall infection rate among the adult population in the Derna region was 8.5%. A significant relationship was not detected between age and the infection rate for this region.

One hundred and four urine samples were collected from the adult male population in the Murzuk region and analyzed for the incidence of S. haematobium. The highest infection rate (10.7%) was found in those between ages 30 and 37, whereas no infection was found among adults over 60 years old (Table 18, Fig. 11). There was a significant (.05 level) relationship between age and infection rate with this group.

In the Sebha region, 96 urine samples were examined for the urinary type of schistosomiasis among the male population. An infection rate of 22.2% was found in adults 20 to 29 years old, and the overall infection rate with S. haematobium for the adult male population was 11.45% (Table 19, Fig. 12). A significant (.05 level) relationship was found between age and infection rates.

Table 18
The Infection Rate of S. haematobium in the Adult Male Population in the Murzuk Region Based on Urine Examination

Age	No. tested	No. positive	% infected
20-29	11	1	9.09
30-39	28	3	10.7
40-49	35	2	5.7
50-59	21	1	4.8
60 & over	9	0	0
TOTAL	104	7	6.73

Table 19
The Infection Rate of S. haematobium in the Adult Male Population in Sebha Region Based on Urine Examination

Age	No. tested	No. positive	% infected
20-29	9	2	22.2
30-39	25	5	20.0
40-49	31	3	8.57
50-59	17	1	5.88
60 & over	14	0	0
TOTAL	96	11	11.45

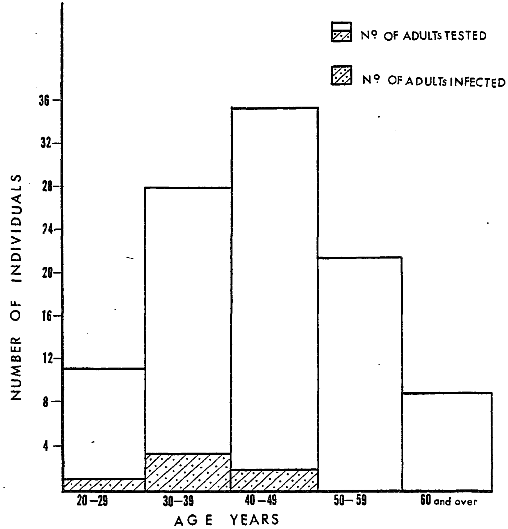

Fig. 11. A histogram of S. haematobium in the adult male population in the Murzuk region (Fezzan).

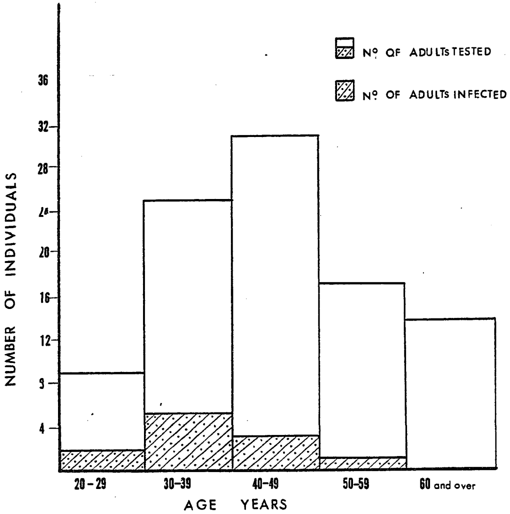

Fig. 12. A histogram of S. haematobium in the adult male population in the Sebha region (Fezzan).

The infected non-Libyan workers in the Fezzan region constitute a danger of introduction of schistosomiasis. Seventy-one urine samples were examined from non-Libyan workers in the Fezzan region. The highest infection rate, 47.05%, was among Egyptian workers; the infection rates among workers were: from Gambia, 40%; from Nigeria, 37.5%; and from Chad and Mali, 33.3%. The overall infection rate among non-Libyan workers in the Fezzan region was 40.8% (Table 20, Fig. 13).

Table 20
The Infection Rate of S. haematobium Based on Urine Examination of the Adult Male Non-Libyan Workers in the Fezzan Region, Listed According to the Worker's Country of Origin

Country of Origin	No. tested	No. positive	% infected
Egypt	34	16	47.05
Chad	18	6	33.3
Nigeria	8	3	37.5
Mali	6	2	33.3
Gambia	5	2	40
TOTAL	71	29	40.8

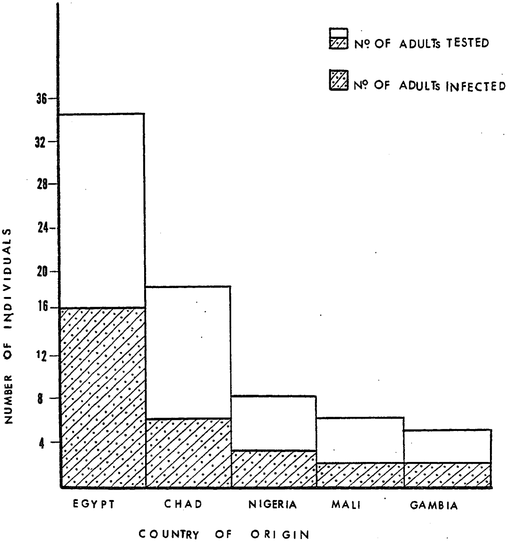

Fig. 13. A histogram of S. haematobium in the adult male non-Libyan workers in the Fezzan region.

CHAPTER V

DISCUSSION AND RECOMMENDATIONS

The environment in Libya is suitable for the survival of both species causing schistosomiasis, S. haematobium and S. mansoni. The study found either one of the two possible species in each region. Other regions that have more than one variety of the disease have been reported, but both varieties were not found in the same region. To prevent both varieties from spreading, precautions should be taken to prevent the spread of the intermediate hosts and the disease. These precautions involve killing the intermediate snail hosts with molluscicides as well as using the most effective medicines on diseased individuals. The available medicines range only from 20% to 30% effective, and there, unfortunately, is not a vaccination that is effective.

In all regions, the host snail of the endemic species of schistosomiasis, either Biomphalaria or Bulinus, was the dominant snail of the local water bodies. The large numbers of these snails makes transmission of schistosomiasis quite likely, even though the snails have a very low incidence of infection.

The incidence of cercaria was found to be 0.63% in Biomphalaria snails and 0.44% in Bulinus snails. These figures seem to be low, but are comparable with results from previous reports.

As indicated, the findings of water chemistry of the three regions show similarities for the values of dissolved material and indicate suitable conditions for snail survival.

In the Fezzan region, the reduction in the use of open storage tanks and the trend to increased use of pipes rather than canals for irrigation should help minimize the spread of schistosomiasis. Control of the spread of the host and disease should be relatively easy in the Fezzan region because of the great distance between oases. The use of habitat reduction for disease control could include governmental help in the transition from open to closed irrigation systems. Inspection and control should be maintained until the disease is eradicated. Detailed record keeping on snail locations and human infections and preparation of maps of such things as infected water sources should simplify planning economical control measures.

In most parts of Libya, the amount of snail habitat is limited and the control of infection by the destruction of snails can give positive results in a short period of time. Physical modification of the habitat, such as elevation of water temperature, can cause death to snails. van der Schalie and Berry (1973) found that higher temperatures in water makes less dissolved oxygen available to aquatic snails. Liang (1974) indicated that temperature is one of the most important of the physical influences in any freshwater biotope. A temperature of 25°C to 30°C represents the optimal range for Biomphalaria and Bulinus snails. The findings of these studies can be applied in the endemic areas of Libya. Because the spring and wells are small, the use of solar energy to warm the water could prevent snail reproduction especially when the water temperature of the water body ranges from 25°C to 28.5°C. Water heaters could be used, but solar heating of plastic-covered small water bodies could be practical and economical.

For the epidemiological study, it was not possible to collect fecal or urine samples from the females because of social and cultural mores. Therefore, a female nurse is needed in any investigation or study dealing with the female portion of the population. A general house to house survey is necessary for the endemic regions of schistosomiasis, Mizurata, Derna, and Fezzan, in order to gather valid data on the infection rate.

This study shows significant relationship between the age of the person and percent infected. The only region in which there was a negative relationship between age and percent infected was in Derna. This phenomenon may be related to the sample size, or the host may carry the disease without passing eggs in certain stages, or the 20-29 age group may have a great resistance to the disease. Therefore, further investigation concerning this phenomenon in Derna is needed.

Infection rate variation could be caused by one or more of the following:

1) Differences in the prevalance of schistosome infected snails as a result of: a) natural causes and/or b) physical or chemical control effects.

2) Differences in exposure to infected snails because of: a) life style and location of water sources and/or b) knowledge of how transmission occurs.

3) Differences in susceptibility and response to treatment because of: a) genetics; b) prior exposure and resulting immunity; and/or c) affect of treatment.

This study did not differentiate between heavy and light infection. Therefore, aspects of the level of infection that bear upon the severity and transmission of the disease are unknown. However, when rates of infection are higher, the probability of reinfection, heavy infection, and severe disease are probably greater.

The results indicated that non-Libyan workers have a high infection rate of schistosomiasis (40%) as compared with that of local residents (9%). Non-Libyan workers also constitute a danger in the spread of the disease because of their greater mobility.

The much higher incidence of schistosomiasis in foreign workers as compared with that of the native Libyan population prompts these questions:

1) Will the incidence of schistosomiasis in foreign workers decline during their stay in Libya?

2) Will the incidence of the disease in Libyans increase due to the high level of disease in foreign workers?

3) Is the incidence related to occupational exposure?

Long term observation is needed to answer the first two questions and additional information is needed to answer the third.

Some recommendations can be made. People that have been exposed to the intermediate host should be 1) screened periodically for the disease, 2) treated if infected, 3) restricted from access to snail-bearing water, and 4) educated about the danger and the mechanism of the transmission of the disease. It is highly recommended that anyone who is infected be prevented from working in the endemic areas. It is also desirable to control, in so far as possible, the movement to and from the endemic foci of people and materials containing live snails. The introduction of infected snails or infected people to a new region can establish the disease cycle.

Control measures should be coordinated with other programs, since poisoning of snails may interfere with the biological control of the mosquito, the vector of malaria.

In conclusion, schistosomiasis is an important public health problem in Libya because of the large area of the country and the distribution of schistosomiasis. Any project using springs or water bodies in the infected regions must consider the schistosomiasis problem because these waters constitute the only habitat of the snail link in the disease cycle in many regions.

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