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BILHARZIASIS SURVEY IN BRITISH SOMALILAND, ERITREA, ETHIOPIA, SOMALIA, THE SUDAN, AND YEMEN *

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SYNOPSIS

A survey of bilharziasis and its vectors in certain countries of north-east Africa and of the Red Sea area, carried out between December 1951 and February 1952, is described within the framework of a review of the somewhat scattered and incomplete information already available on this subject in the literature. Clinical inquiry and microscopic examination of random stool and urine specimens were used to obtain data on the endemicity of the disease, and many samples of suspect mollusc vectors of *Schistosoma haematobium* and *S. mansoni* were collected from varied habitats and subsequently classified. A section on malacology discusses the difficulties of systematization of the African freshwater snails. The need for a fuller investigation of human incidence, particularly in the inland and highland districts, is stressed, and the author suggests measures for the control of vectors, sanitation of water channels, prophylaxis of the disease, health education and legislation, and biological and chemical research. He draws the conclusion that the future economy of these countries depends upon the joint efforts of the physician, the malacologist, the chemist, and the engineer in controlling the spread of bilharziasis from the highly endemic areas to regions where its incidence is still slight.

Between December 1951 and February 1952, the author visited British Somaliland, Eritrea, Ethiopia, Somalia, the Sudan, and Yemen, as part of the WHO-sponsored bilharziasis survey programme initiated in 1949.

* This is the fourth of a series of articles, published in the *Bulletin of the World Health Organization*, describing the epidemiology of bilharziasis in the African and Eastern Mediterranean regions. The preceding articles are :

Gillet, J. & Wolfs, J. (1954) Les bilharzioses humaines au Congo Belge et au Ruanda-Urundi. *Bull. Org. mond. Santé*, **10**, 315

Gaud, J. (1955) Les bilharzioses en Afrique occidentale et en Afrique centrale. *Bull. Org. mond. Santé*, **13**, 209

Gaud, J. (1955) Les bilharzioses à Madagascar et aux îles Mascareignes. *Bull. Org. mond. Santé*, **13**, 259

The present report on this survey also includes some data on French Somaliland (see page 6), which is enclosed within the compact geographical region surveyed, and on Western Aden Protectorate (see page 90-91), which was also visited although not included in the official programme.

In several of the territories surveyed, background information was seriously lacking, and it was not possible to obtain useful leads as a basis for local investigation. Moreover, the follow-up of data contained in the literature presented many difficulties. Nevertheless, much valuable information was obtained, and in this report the author has tried to make as comprehensive a statement as possible on each of the countries visited by integrating the available data with those obtained through personal contacts and investigation.

The following general survey methods were used : In areas where bilharziasis is known to occur, random samples were taken; while in areas with no previously reported history of the disease, an attempt was made to find individuals complaining of its symptoms or exhibiting probable signs. Whenever possible, samples were obtained after exercise involving the abdominal muscles; they were examined microscopically, using the following procedures:

After half an hour's sedimentation in a conical glass, part of the urine sediment was pipetted onto a microscope slide and examined. Whenever the first examination proved negative, the rest of the sediment was centrifuged by a few slow turns of a hand centrifuge and re-examined. With regard to the faeces, a bean-sized piece (about 10 g), taken when possible from a mucous or bloody part of the stools, or, if not, scraped from the surface, was shaken with about 100 ml of normal saline, sieved, sedimented for half an hour, and examined as described above. If repeated examinations gave negative results, another sample was obtained and examined whenever possible. Unfortunately, rectal swabs and scrapings were difficult to procure in the countries surveyed.

Representative and analogous selections of snail samples were sent to two WHO snail-identification centres.[a] A list, with short comments, of the snails which were collected is given separately for each territory, while a fuller discussion is contained in the section entitled Malacological Notes (see page 93). Confusion has long existed as regards the nomenclature and systematic position of the African freshwater mollusca and especially of the family *Planorbidae*, and species identification is still largely provisional. The taxonomy employed agrees with that recommended by the WHO Study Group on Bilharzia Snail Vector Identification and Classification.[100] The older terminology is used only when quoting from an author. Specific names have usually been omitted. Care was, however, taken to differentiate between the two subgenera of *Bulinus* s.l. (formerly

[a] Dr D. M. Blair, Director of Preventive Services, Department of Health, Salisbury, Southern Rhodesia; and Dr G. Mandahl-Barth, Danmarks Akvarium, Charlottenlund, Denmark

bearing distinct generic names : *Bulinus* and *Physopsis*) and also to distinguish the species *Bulinus forskalii*, formerly classified under *Pyrgophysa*.

An authoritative statement concerning the presence or absence of vector snails, snail densities, and human incidences can be made only after multiple and continued investigations. In the author's opinion, careful study, including the use of rectal swabs and biopsies, will reveal a greater incidence of bilharziasis resulting from both *Schistosoma haematobium* and *S. mansoni* infection than has hitherto been recognized. Biopsies have been found to be particularly useful in detecting hidden infections of both forms of bilharziasis which used to be diagnosed clinically as dysentery.

From the basic information gained, it already appears that, in general, bilharziasis is not endemic in the arid lowland and coastal regions bordering on the Red Sea, while one or both forms are endemic in the inland and highland regions on either side of it. In the equatorial lowland territories, however, bilharziasis haematobia is endemic in the two main river valleys of southern Somalia. The presence of both forms of the disease in the Nile basin is too well known to elicit comment. As the economic development of the various countries visited is inevitably linked to an increase in the incidence of bilharziasis, it is particularly important that the situation should not be allowed to deteriorate in regions where its incidence is at present only slight.

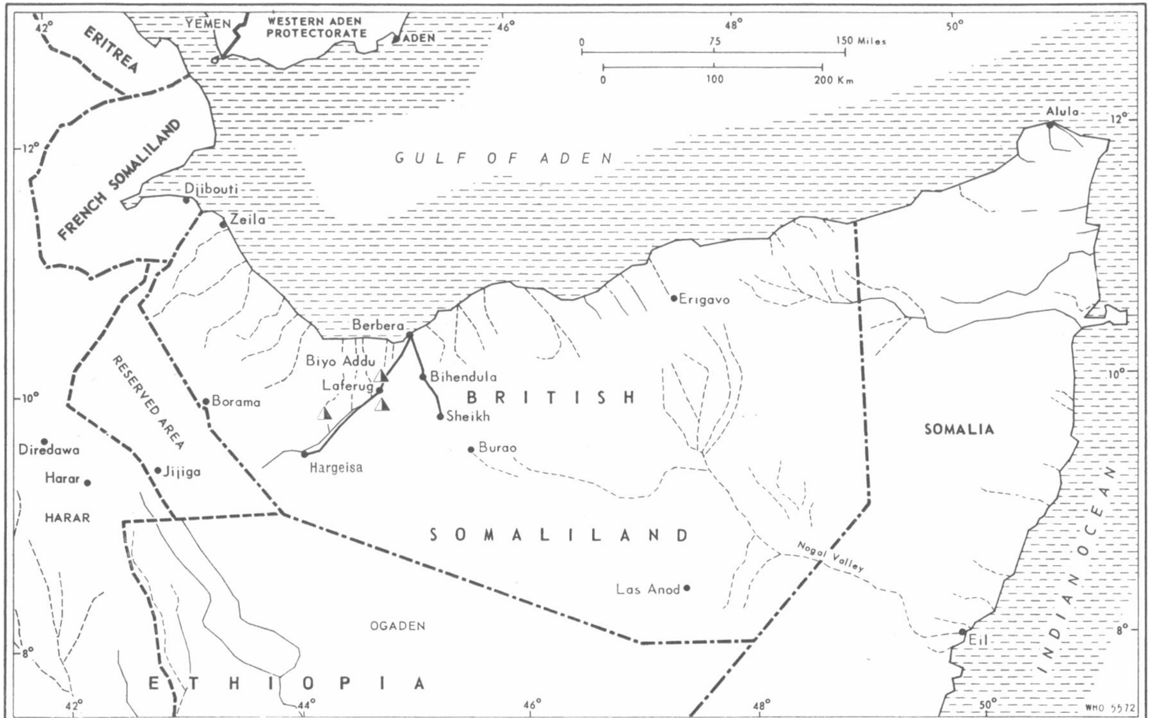
BRITISH SOMALILAND

General Description

British Somaliland (see Fig. 1) lies in the north-eastern horn of Africa and stretches along the greater part of the southern coastline of the Gulf of Aden, between French Somaliland in the north-west and Somalia in the east, while in the west and south it borders on Ethiopia. The territory is situated between latitude 8°N and 11°N and longitude 43°E and 49°E; it measures about 170 000 km² (65 000 square miles) and is occupied by the easternmost continuation of the southern Ethiopian plateau, which, in British Somaliland, slopes gently from northern elevations of above 1500 m (4900 feet) to heights of 1000 m (3300 feet) and below in the south and east. The elevated northern rim of the highlands descends in scarps and broken hills to a coastal plain, wide in the west and narrow in the east.

From the northern scarps, which attract the greatest rainfall, a series of short, intermittent, and seasonal rivers descend. Permanent watercourses are few and usually restricted to the upper courses of the river-beds. The inland plateau has few streams; their beds follow the general line of inclination and drain through the Nogal and other valleys towards Somalia and the Indian Ocean.

FIG. 1. BRITISH SOMALILAND



▲ *Biomphalaria* spp.

Boundaries:

— - — - international

- - - - - - - - other

- - - - - - - - - river-beds

The main rains (" gu ") fall in April and May, before the south-west summer monsoon (" kharif "), which blows from May to September. The little rains (" dahir ") fall in September and October, at the end of the kharif. The cool and dry north-east monsoon (" jillal ") lasts from November to March. The annual double rainfall does not support more than a vegetation of coarse grass, stunted thorn, and acacia trees. Frankincense and myrrh are both obtained from the sap of trees found in the east. The territory harbours lion, ostrich, a variety of gazelle, and kudu, the latter being the emblem of the country. Much of the interior is generally cool and healthy on account of the height. Agriculture is confined to small areas with sufficient rainfall, millet and maize being grown in the western parts. Under a programme of water conservation and agricultural expansion, the excavation of water-storage reservoirs is projected at various points in the country.

The population consists of nomadic Moslem Somali tribes and is estimated at 700 000. The life and wealth of these people is centred around their stock of camels, sheep, and goats. During the rainless summer months, from June to September, a large part of the population moves inland, by agreement with the Ethiopian Government, to the greener pastures of northern Ogaden and the Reserved Area of the adjacent Jijiga region (Harar Province).

Hargeisa, the present capital of the Protectorate, lies at an altitude of 1480 m (4850 feet) and has a population of about 20 000. Berbera, the old capital and port, has a population fluctuating seasonally between 10 000 and 30 000.

Geographical Distribution of Bilharziasis

Review of available data

British Somaliland. On the subject of bilharziasis, only negative reports exist for the Somaliland Protectorate. Lane,[56] in 1936, wrote that "no accounts have come to light "; and the official statement that " the indigenous population of Somaliland is, as it always has been, free from the common helminths ", which was published in the *Medical and Sanitary Report* of the Somaliland Protectorate for 1936,[89] is considered valid to this day.

The surrounding Somali region. It should, however, be noted that bilharziasis mansoni and haematobia have both been reported from the adjacent territories of the Somali region, not very far from the borders of the Protectorate. A *S. mansoni* focus has been described by Giovannola [36,37] at Harar and *Biomphalaria* snails have been reported as common around Harar and towards Jijiga (Ethiopia); these towns lie on a continuous highland plateau which loses altitude slowly and becomes progressively drier towards Hargeisa. Occasional rare cases of bilharziasis mansoni and haematobia have been reported by Mennona & Modugno [69] among the Ogaden and the Hararis respectively. Rossi,[80] in 1939, reported an autochthonous focus of *S. haematobium* from the Wadi Sen Wen, near Tohen, in the very north of Somalia (see Fig. 4, page 34).

Two cases of *S. mansoni* infection have been reported from French Somaliland, an arid country whose only industry is salt production, but whose main town, Djibouti, handles transit traffic between Ethiopia and the outside world. According to Ricci, Leger,[57] in 1930, described the disease in a native of Djibouti who died at Marseilles. Heckenroth & Guilliny,[46] in 1932, reported a case of bilharziasis mansoni in conjunction with *Fasciola hepatica* infection from Benderjedlis.

Survey

The Director of Medical Services, British Somaliland, confirmed the continued absence of bilharziasis, and of any vector snails, from the country, pointing out that, on account of the general aridity and the scarcity of permanent waters, the presence of vector snails was hardly to be expected. His statement was not, however, fully corroborated by the results of investigations made by the author.

Hargeisa to Berbera. Examination of stools and urine from 24 pupils of the Koranic school and from 20 in-patients of the Hargeisa Hospital gave negative results with regard to bilharziasis.

On the road from Hargeisa to Berbera on the coast (about 175 km—110 miles), all bodies of water encountered were examined where they approached the road. A well in the bed of a stream (" tug " = stream) at Dubato and " tugs " at Darburruk, where East Africans had been encamped during the war, and at Sheikh Abdal, yielded no molluscs. In Tug Laferug, just before Laferug village, and also in Tug Biyo 'Addu, situated about 25 km (15 miles) further along the road, *Biomphalaria* snails were found by the author; this discovery probably constitutes the first record of *Biomphalaria* in the territory. The snails, which were found sticking to the protected lower surfaces of stones, were relatively small, possibly immature, but undoubtedly belonging to the true genus *Biomphalaria*, which is a potential vector. Both streams were situated in the foot-hills, at an altitude of 500-600 m (1650-2000 feet); they were shallow with sandy bottoms, had little current, and contained some grasses and algae. Two further streams, Tug Hamas and Tug Daraguli, did not contain any snails.

It was not possible to obtain stool samples systematically at Laferug village. Five random samples, deposited on the ground around the village, were, however, collected; these were negative for schistosome ova. Examination of the stools and urine of 20 pupils of the Berbera primary school, who were drawn from various parts of the country, including Laferug, and of 5 random patients at the hospital, also gave negative results. Various springs at Dubar, about 12 km (7.5 miles) away in the foot-hills, which feed the drinking-water reservoir of the city, were examined and found to contain *Melanoides tuberculata.* A freshwater swimming-pool in Berbera and a drinking-basin in front of the hospital did not contain any molluscs.

Berbera to Sheikh. On the road from Berbera to Sheikh, Tug Menja-'assey, a sluggish, weedy stream, yielded *Bulinus (Pyrgophysa) forskalii* [a] while a similar stream, Tug Bihendula, yielded *Bulinus forskalii* and *Melanoides* both at Bihendula and at Sheikh. Tug Lallis, Tug Heiramadlé, Tug Hudiso, and others contained no snails.

The stools and urine of 21 schoolboys from Sheikh secondary school, who came from various parts of the country and also from Jijiga (Ethiopia), proved negative for bilharziasis.

Results of urine and stool examinations are summarized in Table I and a list of the freshwater molluscs collected is given in Table II.

TABLE I. URINE AND STOOL EXAMINATIONS IN BRITISH SOMALILAND

Locality	Source of material examined	For *S. haematobium*		For *S. mansoni*	
		examined	positive	examined	positive
Hargeisa:					
Koranic school	schoolboys* (9-14 years)	24	0	24**	0
hospital	in-patients	20	0	17	0
Laferug	stools deposited around village			5	0
Berbera:					
primary school	pupils* (9-19 years)	20	0	20	0
hospital	in- and out-patients	5	0	5	0
Sheikh:					
secondary school	pupils* (12-18 years)	21	0	21 †	0
	Total	90	0	92	0

* These individuals came from a variety of places within British Somaliland and also from Djibouti (French Somaliland), as well as from the adjoining areas of Jijiga and Ogaden (Ethiopia).

** One case of *Hymenolepis* in a schoolboy from Wilo Wanagi and one case of *Trichostrongylus* in a schoolboy from Fafan, both of which are situated in the grazing areas of the interior (Ethiopia)

† One case of *Ankylostoma* in a pupil from Tanganyika

[a] For a discussion of the possible vector role of this species, see page 100.

TABLE II. FRESHWATER GASTROPOD MOLLUSCS COLLECTED IN BRITISH SOMALILAND

Serial No.	Place of collection	Description	Species
28	Tug * Laferug	stream near Laferug village on Hargeisa-Berbera road; little current; sandy; algae	*Biomphalaria* sp.** † *Melanoides tuberculata*
29	Tug Biyo 'Addu	same road, similar habitat, tall reeds	*Biomphalaria* sp. *Melanoides tuberculata*
30	Dubar, Berbera drinking water supply	various springs with sandy bottom, some thermal; basins	*Melanoides tuberculata*
31	Tug Menja'assey	halfway, Berbera-Sheikh road, sandy, marshy banks, *Ceratophyllum*	*Bulinus forskalii*
32	Tug Bihendula	near Bihendula, same road, similar habitat: *Ceratophyllum*, *Panicum*, reeds	*Melanoides tuberculata* *Bulinus forskalii*
33	Tug Bihendula	near Sheikh, similar habitat	*Melanoides tuberculata* *Bulinus forskalii*
47	Tug Biyo Di	stream 40 km N.E. of Hargeisa, altitude 1000 m, falling over series of rock-shelves in deep gorge, interspersed with grassy and reedy stretches; snails on weeds and underside of stones	*Biomphalaria* sp. ††

* Tug = stream

** See Fig. 10, and section entitled Malacological Notes, page 93.

† This specimen was identified as *Biomphalaria rüppellii* by Dr Mandahl-Barth (personal communication).

†† This sample was later obtained and sent to the author by Medical Headquarters.

Discussion

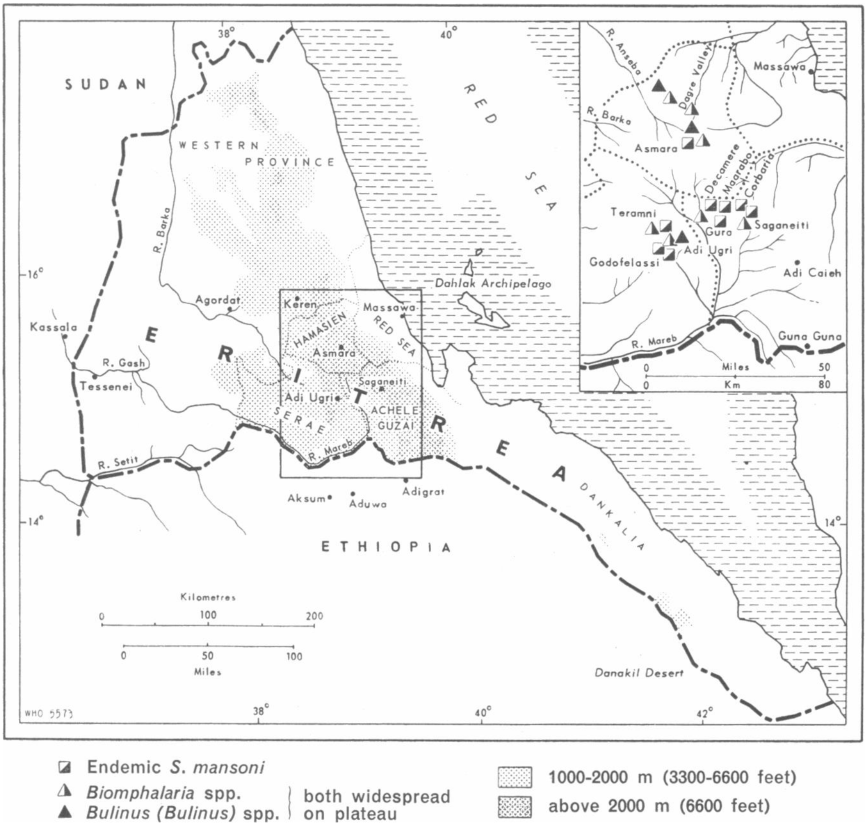
The discovery of *Biomphalaria*, a potential vector of bilharziasis mansoni, aroused much interest. It was realized that the projected water reservoirs might well offer suitable conditions for the establishment and breeding of these snails, and that the matter would require the special attention of the authorities, so as to avoid a possible establishment of *S. mansoni* through the wanderings of the tribes to and from the reserved areas of Ethiopia.

ERITREA

General Description

Eritrea (see Fig. 2), a country of the southern Red Sea group, is roughly a triangle, bounded on the south by Ethiopia, on the west by the Sudan, and on the east by the Red Sea; it continues in a long tail (Dankalia) stretching to the south-east as far as the Bab el Mandeb strait and French Somaliland, thus bringing the total length of its coastline to over 1000 km (620 miles). This territory of 130 000 km^2 (50 000 square miles), which acquired its present boundaries through the Italo-Ethiopian treaty of 1902, does not possess geographical, climatic, or ethnographical unity.[a]

FIG. 2. ERITREA



Running northwards through the middle of the triangle, and gradually sloping downwards from an altitude of about 2400 m to 1400 m (7800-4600 feet), is the northernmost spur of the Ethiopian tableland. This mountainous core is flanked on the west by broad and torrid lowlands, largely homogeneous with the Sudan; to the east, it falls away in a steep escarpment to the narrow coastal plain, which merges, in the southern arm of the country, with the wastelands of the Danakil Desert.

Various seasonal rivers drain in all directions from the central highlands, the most important of them flowing towards the Sudan, between the months of July and September. These are the Baraka and its tributaries, draining to the west and finally to the north, and the river Mareb, called Gash in its

[a] In 1952 Eritrea, at one time the northernmost province of Ethiopia, again joined that country in an autonomous federation.

lower course, which in Eritrean territory flows first south and then west, forming part of the southern frontier. The only perennial river of the territory is the Setit, a tributary of the Atbara, which, coming from Ethiopia (where it is called Takkaze), forms another part of the southern boundary of Eritrea.

The elevated southern and northern plateaux have a perennially cool, clear climate with a double summer-rainfall of about 500 mm (20 inches) between the months of May and September. The western plains, like the adjoining Sudan, also have a summer rainfall typical of the tropical continental climate, averaging about 300 mm (12 inches). The eastern plain belongs to the maritime Red Sea climatic regime, with winter rains and hot and humid summers. The annual rainfall in Eritrea ranges from 750 mm (30 inches), on the steep eastern slopes, to 180 mm (7 inches) on the coastal plain, falling to nil in the southern Danakil Desert which, with its sunken salt lakes, is considered to be one of the hottest parts of the world.

The population of Eritrea is estimated at about one million people, belonging to several racial elements. Roughly speaking, a half of the native population are Christian settled agriculturists living on the southern high plateau, while the remainder, Moslem or pagan, follow a predominantly nomad and pastoral life on the lower northern plateau and in the plains, the tribes of the western plains migrating far into Ethiopia.

Eritrea is deficient in grain production but largely self-supporting in food, and is able to export hides and skins. In the eastern coastal plain, year-round cultivation takes place only in the river-beds. On the eastern slope, with its winter rainfall supplemented by some rain during the summer months, coffee and citrus are now grown on a small scale which is, however, capable of considerable extension. Settled, but not very efficient, agriculture is practised in a large area of the central high plateau; this accounts for the bulk of the agricultural produce. Most of the millet, the native staple grain, comes from the river valleys of the western plains (Gash, Barka, Setit). These form a potentially rich agricultural district which is not fully exploited, partly because of the lack of perennial water, but mainly owing to the nomadic habits of the tribesmen. Settled agriculture is now being developed largely by Sudanese and West African immigrants, which presents a problem of some importance, as they originate from areas where bilharziasis is endemic.

Geographical Distribution of Bilharziasis

Review of available data

Bilharziasis haematobia. In 1914, de Marzo [65] reported that bilharziasis haematobia was non-endemic in the Gash, Barka, and Setit regions, all cases found by him having been imported from Egypt and the Sudan. According to Zavattari,[103] careful personal investigations with regard to the occurrence of the disease in Eritrea in 1930 gave negative results. Girges,[38] in 1934, included Eritrea in his distribution map for *S. haematobium*; he also stated that the disease was present.

Sarnelli,[81] in 1935, assumed as probable a light and diffuse endemicity of bilharziasis haematobia in Eritrea, partly from analogy with the high endemicity of Yemen, which he considers its geographical and climatic counterpart, and partly because he thought it surprising that a disease, endemic in the whole, and especially in the eastern regions, of Africa, from Egypt to the Cape of Good Hope, should have " graciously flown over Eritrea without more than grazing her borders ".[a] He reported that his teacher, Grixoni, as well as de Marzo, had observed the unquestionable presence of imported haematobia cases in Eritrea. Grixoni's statement that " not many autochthonous cases were found ",[b] is also quoted. To these comments Sarnelli added his own observations on the constant danger of introduction and further spread of the disease, in view not only of the steady connexion between Yemen and Eritrea, but also of the considerable number of troops, labourers, servants, and others then moving between these two countries and the other Italian colonies in Africa where bilharziasis haematobia is more or less endemic. In view of these multiple contacts, he thought that the seeming absence of *S. haematobium* from Eritrea, if not merely due to lack of data, might be attributed to a possible absence of vector snails, nothing being then known of the molluscan fauna of Eritrea.

Brunelli [17] in 1934 reported four cases of bilharziasis haematobia in Asmara which had originated in the Hejaz.

No documentation exists on the occurrence of autochthonous cases of bilharziasis haematobia within the present boundaries of Eritrea. Reports are, however, available for eastern Tigre, just south of the Eritrean border, a territory which was temporarily included in Eritrea after the Ethiopian campaign of 1935-36. Three presumably autochthonous cases were seen by Poggi & Monti [77] at the dispensary of Hausien (Hoazien). Corsi,[21] in 1939, also reported three cases of undefined origin among native soldiers.

Bulinus snails (*sensu stricto*) are now known to be common on the southern Eritrean plateau (Ferro-Luzzi [33]), as well as on its southern continuation in Tigre (Poggi & Monti [77]) and throughout the mountainous region of Ethiopia in general (Zavattari [103]).

Bilharziasis mansoni. The absence of *S. mansoni* had been reported by a number of authors before 1935. Thus, for example, Zavattari,[103] who took part in a sanitary mission to Eritrea in 1930 and who specially searched for the presence of bilharziasis, reported negative results in all surveys. Girolami,[39] in 1935, though mentioning the presence of " *Planorbis* "

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[a] "... sorvolare graziosamente l'Eritrea, dopo averla sfiorata da ogni lato."

[b] " Di casi autoctoni non ne sarebbero stati trovati molti."

boissyi in Eritrea, stated that indigenous cases of the disease had never been found. Almost simultaneously, Satta,[82,83] in a preliminary note (1934) and in a later detailed article, gave the first indication of autochthony by describing a focus where two Italians had contracted infection with *S. mansoni.* One of them showed him the pool in question, situated at about 25 km (15 miles) north of Asmara, near Coazien, at an altitude of 1150 m (3800 feet) in the bed of the torrent Dadda, which flows into the Dagre valley. There Satta found numerous *Biomphalaria,* many of which emitted bifurcated cercariae. The area is reported to be very thinly populated and the inhabitants from the nearest settlement were not found to be infected. The second case, who had returned to Italy, was described by Diena [31] in 1935. D'Amico,[4] in 1938, reported from Massawa infection with *S. mansoni* in two native boys who had originally come from Saganeiti, a locality which is now known to be endemic.

A systematic survey for intestinal parasites, conducted by Sofia & Ciaravino,[88] in 1944, among 700 in-patients of the Regina Elena Hospital in Asmara who were not, at the time, suffering from gastro-intestinal symptoms, showed six cases of *S. mansoni* (0.86%). The origin of these cases was not ascertained. In the same year, Mariani-Tosatti [64] reported three infections in European children, who had contracted the disease in an affluent of the River Mareb, 35 km (22 miles) south of Asmara on the Adi Ugri road and in a stream near Toselli village, 4 km (25 miles) from Decamere.

Ferro-Luzzi,[33] in a recent comprehensive study of intestinal bilharziasis in Eritrea, noted that the number of patients appearing in the records of the Regina Elena Hospital at Asmara during the 20 years before 1946 was only 11, while it was 7 for the single year 1947, which made him suspect a slow, but steady, increase in the incidence of the disease. Realizing the indubitable endemicity of intestinal bilharziasis and following-up the origin of patients, he discovered several new foci of endemicity, all in the highlands of Asmara. In Ma'araba village (altitude 2100 m—7000 f et), near Saganeiti, where a number of persons had died from severe haemato-mucous diarrhoea, 28% of the adults and 20% of the children were found to be infected, and infected *Biomphalaria* were located. In Szo'olot village (altitude 2400 m—7800 feet), 15 km (9 miles) from Asmara, 13% of the inhabitants were infected, and infected *Biomphalaria* snails were found in the stream used by the villagers. Infections were also found in other villages, situated mostly in an area comprised between Asmara, Saganeiti, and Adi Ugri, and including Decamere, Gura, Corbaria, Teramni, Godofelassi, and other places. Numerous *Biomphalaria* were shown to occur in the waters of the region, especially in the slow-flowing channels containing aquatic vegetation and the seepage water collections.

Biomphalaria snails were also found by the same author on the western slope (Elaberèt stream, altitude 1600 m (5250 feet)) and on the eastern slope (torrent Sabur at the Fonte del Capitano, altitude 1'400 m (4600 feet)); bilharziasis is not known in these regions, but might evidently be introduced there. Ferro-Luzzi did not find any of the molluscan species he considers " suspect "—*Biomphalaria*, *Bulinus*, and *Lymnaea*—in the lowland plains, including those of the Gash and Setit, where the disease is not known to exist.

He suspected the presence of other highland foci of intestinal bilharziasis, especially towards the border of Ethiopia. He fully agreed with Zavattari [103] that the disease must be of recent introduction in Eritrea, and strengthened his argument by the observation that the greater part of the infected persons are as yet only carriers, and that symptoms, when present, are comparatively mild. He stated that infection is acquired in repeated small doses in the relatively few streams and pools from which all household water is obtained and which are generally used for washing and bathing. He believed that the utter lack of discipline in the deposition of faeces, which is the most important factor in the maintenance and further spread of the disease, could and should be controlled; he also advocated the destruction of snails, health education of the population, and the treatment of positive cases.

Survey

Permission was obtained from the school hygiene authorities to take samples of excreta from students and pupils, of which there are about 6000 in Asmara alone. Valuable information was also obtained from local doctors. The only case of bilharziasis haematobia encountered in 139 urine examinations was in a boy who had previously lived in Hadhramaut, southern Arabia. *S. mansoni*, as expected, was found in various localities. Infestations with other intestinal parasites were also noted during these examinations.

Asmara region. Asmara is inhabited by about 80 000 Eritreans, approximately 15 000 Italians, and several small foreign communities, including Sudanese and colonies from Yemen and Hadhramaut.

Examination of the excreta of 51 pupils of the Akrea school, the Koranic school, and the technical secondary school in Asmara revealed only one case of bilharziasis mansoni.

Akrea pond, a permanent body of water on the outskirts of Asmara, was found to contain snails of the subgenus *Bulinus*. In the pool from which the drinking-water supply of the city is drawn, and which consists of a stretch of water ponded back behind a dam about 14 km (9 miles) away from the town, *Biomphalaria*, *Bulinus* s.s., and *Lymnaea* snails were found on the stones and among the aquatic vegetation (*Polygonum*). Various other streams in the vicinity and a large pond in a nearby agricultural concession did not yield any snails.

The endemic southern highland region. A few streams were examined in the Marazzani Concession near Teramni (Tari 'Amni) where, according to Wright,[101] the occurrence of infection with *S. mansoni* has been reported. No snails were found in the streams, which contained little water at the time. *Biomphalaria* and *Lymnaea* were, however, found in cemented channels in the vicinity.

In Decamere, formerly the second largest settlement in Eritrea, 10 urine samples but only 3 stools could be obtained at the police school, to which students come from diverse regions of the country. These specimens all gave negative results for bilharziasis, while a corresponding random survey of the local population revealed 1 case of bilharziasis mansoni out of 7 stools examined. In nearby Ma'araba village, samples were obtained from 6 villagers of which 1 was positive for this infection.

At Saganeiti school, 3 out of 6 pupils examined were found to be infested with *S. mansoni.*

At Adi Ugri hospital, the doctor had no knowledge of the presence of any bilharziasis cases. Examination of 3 random stool samples from out-patients who happened to attend for other complaints (fractures, etc.), revealed 2 positive for *S. mansoni.* It was in Adi Ugri that the haematobia case from Hadhramaut, already mentioned, was detected among the 12 samples obtained at the Moslem school. Examination of a nearby stream, named Adikuar, which contained *Panicum,* revealed the presence of *Biomphalaria, Bulinus* s.s., and *Lymnaea.*

At Godofelassi, an endemic village in the vicinity of Adi Ugri, the stools and urines of 5 pupils were examined with negative results.

The southernmost portion of the plateau is suspect for *S. mansoni,* but no examinations in this area were possible.

Red Sea Province.

Various examinations for snails of the streams crossing the steep, serpentine road which descends to the Red Sea port of Massawa gave negative results.

At Massawa, the government hospital was visited and it was learned that bilharziasis was not endemic in the area. Stool and urine examinations were conducted among the inmates of an institution for illegitimate children, attached to a convent, with negative results for bilharziasis.

Keren area, Western Province. All waters encountered were surveyed for snails. Two streams, Mai Tokkar and Mai Nmekka' ("mai"= water), situated at 16 and 17 km (10 and 10.5 miles) respectively, from Asmara, were found to contain *Biomphalaria, Bulinus* s.s., *Burnupia, Gyraulus,* and *Segmentina,* together with a vegetation of grasses, reeds, and algae. Another stream, Mai T'abbar, 28 km (17 miles) from Asmara, with a similar vegetation, contained *Biomphalaria.* The other streams, as well as three lakes in the neighbourhood of Keren town, yielded no snails.

TABLE III. URINE AND STOOL* EXAMINATIONS IN ERITREA

Locality	Persons examined		For *S. haematobium*		For *S. mansoni*	
	age (years)	sex	exam-ined	posi-tive	exam-ined	posi-tive
Hamasien Province						
Asmara:						
Akrea school	9-15	♂	11	0	15	0
Koranic school	7-13	♂-♀	20	0	15	0
Technical secondary school	15-18	♂	20	0	20**	1
Decamere:						
random population	20-45	♂	10	0	7	1
police school	24-29	♂	10	0	3	0
Ma'araba:						
villagers	4-25	♂	6	0	6	1
Achele Guzai Province						
Saganeiti:						
school	5-16	♂	8	0	6	3
Serae Province						
Adi Ugri:						
Moslem school	12-16	♂	12	1 †	11	0
hospital	19-62	♂	5	0	3	2
Godofellasi:						
school	6-30	♂	5	0	4	0
Red Sea Province						
Massawa:						
home for illegitimate children	under 15	♂	12	0	11	0
Western Province						
Keren:						
hospital	14-16	♂-♀	20	0	20	0
	Total		139	1 †	121	8

* Other intestinal parasites found among the 121 stools examined were: 12 *Hymenolepis*, 3 *Taenia*, 2 *Ankylostoma*, 2 *Ascaris*, 2 *Oxyuris*, and 1 *Trichocephalus*.

** The case infected with *S. mansoni* had ova both in stools and urine.

† The case infected with *S. haematobium* came from Hadhramaut, southern Arabia.

The stools and urine of 20 male and female in-patients at the hospital in Keren proved negative for bilharziasis ; the results of these examinations are summarized in Table III and a list of the freshwater molluscs collected is given in Table IV.

TABLE IV. FRESHWATER GASTROPOD MOLLUSCS COLLECTED IN ERITREA

Serial No.	Place of collection	Description	Species
	HAMASIEN PROVINCE		
	Asmara:		
1	Drinking water supply	dammed-up pool, 14 km (9 miles) north of town: *Polygonum*	*Biomphalaria* sp. *Bulinus (Bulinus)* sp. *Lymnaea natalensis*
4	Akrea pond	muddy bottom, *Panicum*	*Bulinus (Bulinus)* sp.
6	Asmara-Keren road: Mai Tokkar at km 16 Mai Nmekka' at km 17	streams containing grasses, reeds, algae	*Biomphalaria* sp. *Bulinus (Bulinus)* sp. *Gyraulus costulatus* Krauss * *Segmentina* (prob. *angusta*) ** *Burnupia* (? *abyssinica* Jickeli) *
5	Mai T'abbar at km 28	stream, same road similar habitat	*Biomphalaria* sp.
	SERAE PROVINCE		
	Adi Ugri:		
2	Adikuar stream	*Panicum*	*Biomphalaria* sp. † *Bulinus (Bulinus)* sp. † *Lymnaea natalensis*
3	**Teramni:** Farm near Marazzani concession	cemented channels	*Biomphalaria* sp. † *Lymnaea natalensis*

* The species thus marked have been identified by Mandahl-Barth (personal communication).

** This species was identified by Blair (personal communication).

† See Fig. 10, and section entitled Malacological Notes, page 93.

NOTE:

(1) The Eritrean forms of:

(*a*) *Biomphalaria*, formerly designated *Planorbis boissyi* by various authors, and *P. boissyi*, var. *asmarica* by Satta [83] have been given as *P. rüppellii* by Giovannola [37] and as *Biomphalaria rüppellii* by Mandahl-Barth (personal communication); Ferro-Luzzi [33] differentiates two species, *P. rüppellii* and *P. abessynicus* [sic] Jickeli, according to identifications by Professor Piersanti. Schwetz [85] reports that he has agreed with Dr J. Bequaert, of the Museum of Comparative Zoology, Harvard University, Mass., USA, to consider the various forms known as *rüppellii*, *adowensis*, *pfeifferi*, etc., synonymous and closely related to *boissyi* (*alexandrinus*) (see section entitled Malacological Notes, page 93).

(*b*) *Bulinus* s.s. are given as *B. sericinus* by Mandahl-Barth (personal communication) and as *B. raymondi* by Ferro-Luzzi,[33] on the basis of identifications by Piersanti. The author, who is accustomed to classifying the very variable forms of *Bulinus* occurring in Egypt as *B. truncatus*, noted that the elongated shell type of the Eritrean *Bulinus* did not quite fall within the variation range commonly met in Egypt. It should also be noted that Annandale [6] considers all the *Bulinus* of North Africa and Western Asia as synonymous, with the possible exception of *B. raymondianus* (? *raymondi*).

(2) *Lymnaea natalensis* Krauss, 1848, is considered synonymous with *Limnaea cailliaudi* Bourguignat, 1883.

(3) *Gyraulus costulatus* Krauss shows but little differences of shell conformation from the Egyptian species of *Gyraulus*, that is *G.* (*Planorbis*) *mareoticus* Letourneux and Innes.

Discussion

S. haematobium *infection*

It is known that, in the past, not inconsiderable numbers of Sudanese and West African pilgrims coming from endemic areas used to travel to the Hejaz via Massawa (see page 55 and Fig. 8). It has also been shown that there can exist no doubt as to the presence, in Eritrea, of a number of bilharziasis haematobia cases of evidently imported or undefined origin (Arabs, Yemenites, Sudanese, and others). Snails of the subgenus *Bulinus* are known to be common in the highland region.

Even if the majority of the western Sudanese or West Africans do not frequent the highlands where *Bulinus* s.s. occurs, this is not true of the Arabs and Yemenites, and the *S. haematobium* case from Hadhramaut found by the author in Adi Ugri, where *Bulinus* also occurs in the village stream, indicates that actual opportunities for introduction do seem to exist. Nevertheless, endemicity of bilharziasis haematobia is not evident. The reasons for the apparent absence of endemicity are difficult to gauge. It is conceivable that the local type of *Bulinus*, like the *Bulinus tropicus* of Equatorial and South Africa, is not acting as a vector ; however, in the adjacent regions of northern Ethiopia, *S. haematobium*, in conjunction with *Bulinus* s.s., is reported as common (see page 11) while *Bulinus* (*Physopsis*), as far as the author is aware, has not been reported from the northernmost part of Ethiopia.[a]

It should also be noted, as a parallel, that *S. haematobium* has only of recent years begun to establish itself in the Gedaref area of the Sudan, situated west of the Eritreo-Ethiopian border (see also page 76).

The possibility of a development, analogous to the taking-root of *S. mansoni* in Eritrea within the past two decades, should be borne in mind, and surveys, or at least checks, for *S. haematobium*, especially among schoolchildren and recruits, should not be neglected.

Experimental infection of the local *Bulinus* snails with *S. haematobium*, similar to the experimentation conducted by Ferro-Luzzi [33] with *S. mansoni* on *Biomphalaria*, would be most valuable and interesting.

S. mansoni *infection*

Study of the available information indicates quite clearly the first discovery and the gradual spread of bilharziasis mansoni in the Eritrean highlands since 1935, the disease being as yet mild and frequently asymptomatic. The view that the disease has established itself only recently might be explained by improved communications connected with the Italian colonization, as suggested by Sarnelli,[81] and by the effects of the Italo-

[a] The author did find *Bulinus (Physopsis)* in Lake Tana and in the Blue Nile near its outlet (see page 27) but nothing is known about the northern limits of distribution of this subgenus.

Ethiopian campaign, as indicated by Zavattari.[103] A real increase in incidence occurred after the Second World War, no doubt in connexion with the extensive movements of troops and populations. The author agrees with Ferro-Luzzi [33] that the disease is liable to further increase in incidence, severity, and importance.

Under the present system, cases detected and treated are few and of little epidemiological consequence. The general problem, compared to that existing in the agricultural irrigation countries, is relatively limited. The schistosome foci on the plateau are not too numerous, neither are the waters which both contain *Biomphalaria* and are used by the population. Snail control in the various rocky pools of permanent water and in the infested streams of the highlands does not present insurmountable technical difficulties; the use of molluscocides would offer good results in such limited snail habitats as exist.

Bilharziasis mansoni cases could be sought out and treated without too much difficulty. Should a determined effort be made at this stage, a good chance would exist of checking the disease. Such action in this limited area would indeed furnish excellent experience and interesting indications as to what might be achieved in larger areas, such as Ethiopia.

ETHIOPIA

General Description

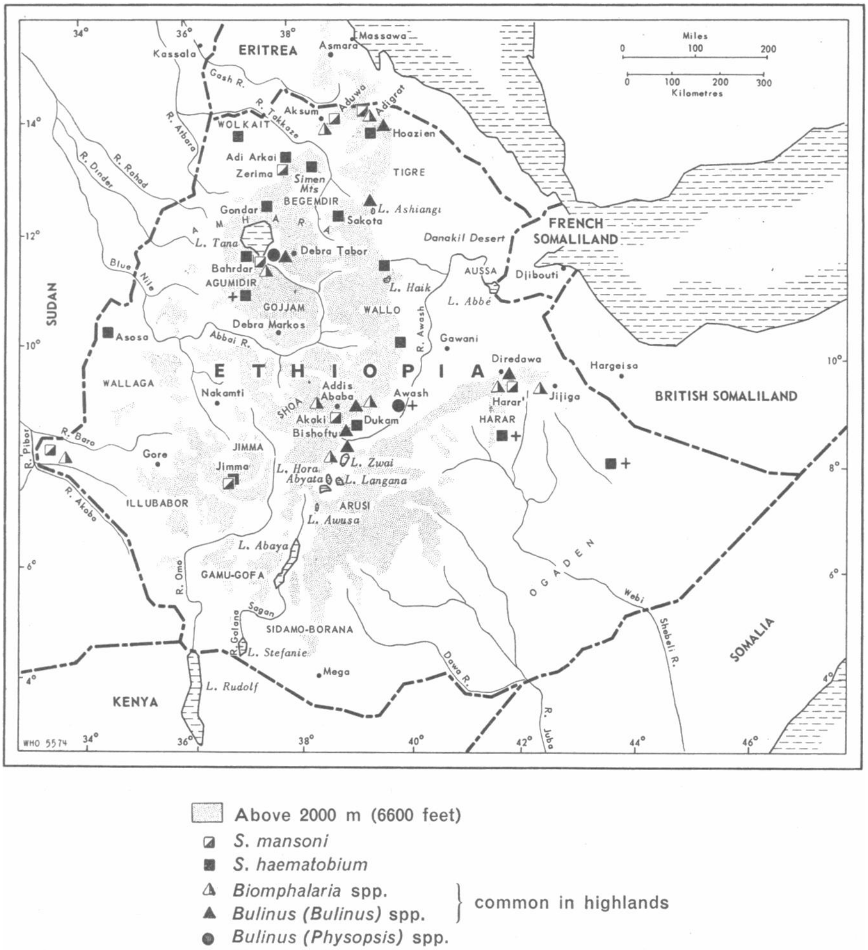
Ethiopia (see Fig. 3), as it appears on the modern map, was created in the 19th century by Emperor Menelik II, who vastly extended his dominions to the south and south-west. The kingdom, as re-established since 1941, is bounded on the north and north-east by Eritrea,[a] on the east by the French and British Somalilands, on the south-east by Somalia (formerly Italian Somaliland), on the south by Kenya, and on the west by the Sudan. The country covers an area of about 900 000 km² (350 000 square miles), comprised between latitudes 3°N and 15°N, and has an estimated population of 15 million.

This territory can be roughly divided into a green and fertile inland mountain mass, the most extensive and consistently high in Africa, and a surrounding lower semi-desert or desert terrain. The Ethiopian highland region, which possesses perhaps the finest climate and most splendid scenery of the continent, has given its name to a characteristic fauna and flora extending far beyond its borders.

The topography of these uplands is extremely complicated. Roughly speaking, the main, central, and northern highlands are divided from a less elevated south-eastern section by the Ethiopian sector of the East African Great Rift Valley, which runs in a north-north-easterly direction from

[a] See footnote *a* on page 9.

FIG. 3. ETHIOPIA



Lake Rudolf to the Danakil plains. In the main, the northern plateau is tilted westwards and drains, through the Blue Nile and Takkaze-Atbara systems, into the main stream of the Nile. These rivers and their tributaries flow in chasms of tremendous depth and carry, during the rainy season, a prodigious quantity of water amounting to 90% of the floodwater of the Nile. Only two rivers do not drain to the west: one, the Awash, runs to the north-east to end in the great Lake Abbé at the border of French Somaliland, and the other, the Omo, runs to the south, to complete its course in Lake Rudolf. The south-eastern mountains drain towards the Indian Ocean, mainly through the Juba and the Webi Shebeli.

Both to the east and west, the main Ethiopian highlands drop precipitously to the surrounding desert plains. The great eastern escarpment, which falls abruptly from over 2000 m to about 1000 m (6600-3300 feet), is regarded as the western wall of the Great Rift Valley, which here widens to include the Danakil Desert and the Red Sea.

The greater part of the main Ethiopian plateau lies at altitudes between 2000 m and 3000 m (6600-9900 feet) and enjoys a temperate climate although situated only a few degrees from the equator. The plateau is topped by ridges and isolated volcanic cones, rising to 4000 m (13 200 feet) or above. In certain central sections, it consists of undulating expanses of grasslands; further north, the level plateau is rent by river valleys which cut in so abruptly that one may walk almost to the verge of the descent without suspecting that a break lies ahead. In other parts, denudation has created a chaos of mountains of great complexity.

The Ethiopian region lies in a summer rainfall zone, most of the rains falling in two rainy seasons—the " little " and the " big " rains. The little rains generally occur in March and April. The big rains vary considerably in duration, lasting, for example, from July to August at Adigrat in the north, from June to September at Addis Ababa in the centre, and even longer in the south-west. Usually, however, there are rains during every month, even in the so-called dry season. The rains, which are sudden and violent and occur in conjunction with strong winds, fall mostly after 12 noon and are rare in the mornings. They produce widespread local inundations. In general, rainfall is copious, amounting approximately to over 1000 mm (40 inches) per year in areas lying above 2000 m (6600 feet). The major part of the areas enclosed within the 1000-mm isohyet extends across the main plateau in a belt sweeping across, in a north-north-easterly direction, from Uganda, and just including Lake Tana and Addis Ababa within its margins. The highest rainfall within this zone centres around Gore, in the south-west, which has an annual rainfall of 1900 mm (75 inches). From the periphery of this belt the rainfall gradually decreases in all directions, falling to about 500 mm (20 inches) in the north, towards Eritrea, and to even less in the eastern and south-eastern territories, while the rainfall is practically nil in the lowland deserts.

In the highlands (1800 m—5900 feet—and above), temperatures seldom reach 30°C, the mean monthly maxima ranging from 24°-27°C throughout the year (Adigrat, Harar). The mean monthly minima are usually about 12°-15°C lower. A large diurnal variation is, however, found in the north during the dry (winter) season, when temperatures drop by about 20°C —that is, to 3°-4°C at night.

In general, Ethiopia is a well-watered country with many lakes, rivers, springs, and wells; even on the borders of French Somaliland, there is said to be ample subsoil water at a depth of 7-14 m (23-46 feet). The highlands are mostly deforested grasslands, but belts of closed forest are found along the contours of the great scarps and river valleys, always below the 2000-m (6600-foot) line. In south-western Ethiopia, where the average land level is not so high, more tropical conditions prevail, frequently with luxurious vegetation and subtropical forest country.

In the main, the country is of high fertility and the variations in altitude, climate, and rainfall make it suitable for a variety of crops and for animal pasturage. The chief industries of the country are agricultural and pastoral, the former prevailing among the settled agriculturalists (approximately eight million) of the heights, the latter predominant among the nomad tribes (approximately seven million) of the lower reaches.

The present-day Ethiopians of the plateau are descended from tribes from southern Arabia, more or less amalgamated with the earlier Hamitic population. They are real mountain people who like to build their villages on the topmost ridges and never, if it can be avoided, come down to lower levels. These habits have developed partly for reasons of safety and partly because the highlands are generally healthier and free from malaria. Colonization of the highlands by south Arabian tribes began in early historic times. The immigrants brought with them the plough and agricultural practices of a high standard (terracing and irrigation). One of the immigrant tribes was the " Habashat ", a name which was later applied to the colonists in general, and from which the former name of the country—Abyssinia (" el Habasha " in Arabic)—is derived.

Colonization began in the northern extremity of the highlands, corresponding to the present province of Tigre and highland Eritrea ; here arose the first and powerful kingdom of Aksum which, from the 4th century onwards, adopted the Christian faith. In subsequent centuries, contacts with the outside world were few, but each time the curtain was lifted an isolated, independent, growing empire was found to exist, whose centre of gravity was steadily shifting to the south; the seaboards of Ethiopia were, however, conquered by Islam.

The dominant highland race of today is the Amhara, numbering about two million, who have closer Hamitic affinities than the Tigreans and whose language is fast becoming the lingua franca of Ethiopia. About half the total population, however, is formed by the Gallas, a Hamitic, agricultural and pastoral people of the middle levels who have been penetrating from the south. The nomad population of the eastern and south-eastern deserts is formed by the Hamitic Danakil and Somali tribes. The various negroid and Nilotic peoples of the south-west have been integrated in comparatively recent times.

Conditions in Ethiopia are still largely mediaeval, although the country is definitely moving towards reform and modernization. The Ethiopian is a good peasant farmer, but full agricultural exploitation cannot be expected in the near future.

Geographical Distribution of Bilharziasis

Review of available data

Ethiopia has been placed for some time past, on the basis of extremely generalized information, in an area of endemicity for bilharziasis haematobia, Girges, in 1934, reporting that " it occurs in Abyssinia ". Precise documentation, however, is both scarce and comparatively recent, and is mostly contained in the Italian literature published between 1933 and 1940.

Zavattari, in 1938, discussing various, then recent, reports in a review of the situation declared that :

> " The Italian conquest of Ethiopia [1935-36] with its enormous movements of metropolitan as well as native populations, with the opening up of the ancient barriers which had isolated the empire of the Negus from the surrounding regions, with the activation of commercial exchange and therefore intensification of traffic from one region to another, and with the introduction of coloured troops from Libya and other non-Ethiopian countries, has profoundly changed the static condition in which that country had so long remained ". [a]

He believed that these new conditions had already, in that short time, resulted in the importation of intestinal bilharziasis and in the extension of the foci of vesical bilharziasis, and that a further spread of both forms of the disease to new territory was to be expected in view of the favourable environmental conditions. With regard to the malacological freshwater fauna of Ethiopia, he remarked that information is scattered in a considerable number of publications, mostly illustrating the collections made by various explorers and travellers, and that these publications contain, at best, fragmentary data, many of which require critical revision. From the data at his disposal he reported the occurrence of both *Bulinus* proper and *Biomphalaria* in Ethiopia, the former being present " in the entire mountainous region of Abyssinia ", [b] while the distribution of the latter is described as irregular. As regards *Bulinus (Physopsis)* it is stated that the subgenus has not been cited as appearing in Eritrea or Abyssinia. The author, however, has found a record of *Bulinus (Physopsis) soleilleti* from the Awash River and Lake Haussa in Pilsbry & Bequaert.[76]

Two years later (1940), the information available on bilharziasis was summed up by Ricci [78] in a general helminthological review of Italian East Africa, in which he also endorsed Zavattari's opinion concerning the recent introduction of bilharziasis in various areas and the danger of ultimate propagation of the disease.

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[a] " La conquista italiana dell'Etiopia, con l'enorme movimento di masse, sia metropolitane che indigene, con l'apertura delle antiche barriere che isolavano l'Impero negussita dalle regioni circostanti, con l'attivarsi degli scambi commerciali e quindi con l'intensificarsi delle carovane che si spostano dall'una all'altra regione, e infine con l'apporto di truppe di colore provenienti tanto dalla Libia, quanto da altri paesi extraetiopici, ha profondamente mutato il quadro statico nel quale si trovavano quelle regioni ... "

[b] " ...in tutta la regione montana dell'Abissinia... "

Only brief information can be added to Ricci's review both for the period it embraces and for the period following it. The data available on the large and varied Ethiopian territory are grouped below by geographical region rather than in strict chronological order.

Ganora,[34] to whom is owed the first trustworthy if vague report, in 1933 claimed that bilharziasis haematobia was common in " Amhara " territory—an area which roughly corresponds to the present north-western Province of Begemdir and part of the adjacent Gojjam Province. The subprovinces or regions specifically quoted are : Agumedir (Agumidir), south of Lake Tana ; Bembia (? Dembea), north of Lake Tana ; Semien (Simen), a high mountainous terrain adjoining the north-eastern province of Tigre ; Hoggara (possibly Noggara), a town near the Sudan border in the extreme north ; and Wolkait, a region lying just south of the River Setit, which is the name given to the lower course of the River Takkaze before its junction with the Atbara.

L'Abbate,[55] in 1939, brought evidence in support of Ganora's statements by reporting a *S. haematobium* infection in an Italian subject who had acquired it either in the Little Abbai, an affluent of Lake Tana, or in the lake itself. Further confirmation was furnished by Lombardi [60] in 1940, who reported two haematobia cases from this area : one from Adi Arcai, a town west of the Simen mountains, the other from Dahar Dar (Bahrdar), on Lake Tana, where *Bulinus* s.s. and *Biomphalaria* had been found. This same author also extended the reported area of distribution eastwards by recording two other haematobia cases, one from Lake Haik, in Wallo Province, not far from the eastern escarpment, and the other from Socotà (Sakota), a town further north towards Tigre.

Tigre Province itself, in the north-eastern part of the Ethiopian highlands, was first incriminated in 1938 by Poggi & Monti,[77] who found three cases of bilharziasis haematobia at Hausien (Hoazien) (upon examination of 364 samples of urine and faeces (Ricci [78])). The first record of *S. mansoni* for this same region is also given by these authors, who reported one case discovered at the dispensary of Adigrat. No case histories are given, but in view of the reported presence of both *Bulinus* s.s. and *Biomphalaria* in the perennial swamps of the region, the cases are considered autochthonous by Zavattari [103] in his assessment of the situation. Scarpa,[84] in 1940, reported a case of bilharzia mansoni from the region of Adowa (Aduwa).

In 1938, the first well-authenticated report of *S. mansoni* west of this region—that is, west of Begemdir—was given by Mennona.[68] In view of the clinical symptoms, a search was made for the ova of *S. mansoni*, which were found in the stools of an Italian, who, although he had spent two years in Wallo and Tigre Provinces—namely in Macalle, Socotà (Sakota), Waldié (Waldia), and Ucialli—developed symptoms only several months after his arrival at Adi Arcai-Zerima (1200 m—4000 feet) in Begemdir. In 1940, Scarpa [84] reported three further cases who had acquired their infection in the Zerima, a stream descending from the Simen Mountains south of Adi Arcai.

With regard to the central province of Shoa, little information is available in the literature. Negative reports were given for Addis Ababa by Nägelsbach,[71] in 1934, with regard to *S. haematobium*, and by Mariani,[63] in 1938, with regard to *S. mansoni*. Famigliari,[32] in 1938, did not find either form of bilharziasis in the commissariat of Bishoftu (south of Addis Ababa) but in 1939 L'Abbate[55] drew attention to one haematobia case suspected of having acquired his infection in Lake Bishoftu ; this case has also been cited by Scarpa [84] and others (and see page 25).

In the eastern province of Harar, Giovannola,[36] in 1938, reported two evidently autochthonous cases of bilharziasis mansoni which he had observed in 1936 in two native boys of Harar town. He found numerous *Planorbis* (*Biomphalaria*) *adowensis* in a pool of a nearby stream, where the boys used to swim, and was able to infect these experimentally from the faeces of one of his patients. This record not only represents the first observation of *S. mansoni* in Harar and in Ethiopia, but also the first report of *B. adowensis* as an intermediate host. With regard to *S. haematobium* in these parts, the only record is that of Mennona & Modugno,[69] in 1937, who reported rare cases among the Hararis and the Ogaden tribes of the south-eastern pasture lands.

The relatively arid south of Ethiopia, along the Kenya border, is considered to be free from bilharziasis. Zavattari [103] conducted an investigation, in 1937, with entirely negative results, along the Dawa River, the western affluent of the Juba, and in the Borana territory of southern Sidamo Province. The same apparently does not hold true across the border, where Blair,[16] quoting the Kenya Medical Department, reported the presence of bilharziasis haematobia infections near semi-permanent waterholes in the arid northern province.

For the Galla territory of the south-west of Ethiopia, a negative report was made by Ricci,[78] based on the findings of the Sagan-Omo Biological Mission of 1939 which " made it possible to state with sufficient certainty that the disease [*S. haematobium*] is absent, at least in the zone of the south-west comprised between Mega and Calam ".[a] Orlandini,[72] in 1939, while making an ichthyological survey of various Rift Valley lakes, found potential intermediate hosts for both parasites in the region of Lakes Margherita (Abaya), Awusa, and Langana.

Concerning the west of Ethiopia, Orlandini,[73] also in 1939, reported one case of *S. mansoni* infection from the Ethiopian plains bordering on the Sudan, in the zone comprised between the rivers Baro, Pibor, and Akobo. The case was found during the examination of 150 stools from

[a] " ... permette di asserire con sufficiente certezza l'assenza della malattia almeno in tutta quella zona del O.S. che è compresa tra Mega e Calam." (page 246)

recently enlisted local recruits. "*Planorbis*" (*Biomphalaria*) snails are reported to be abundant in this region. Nägelsbach,[71] in 1934, declared that bilharziasis haematobia was absent from Gore, the capital of Illubabor Province, due to a lack of favourable conditions for the development of the molluscan vectors (see also page 32). The latest information, concerning a double infestation with *S. haematobium* and *S. mansoni* from Jimma, in Kaffa Province, also in the west, was given by Cossar [22] in 1950. A case-history could not be obtained as the patient, a Galla, was brought to Jimma hospital in a moribund condition with a two-days' retention of urine, heavy haemato-mucous diarrhoea, and pronounced ascites. Ova of *S. haematobium* were found in the urine, while ova of both *S. haematobium* and *S. mansoni* were present in the stools.

Survey

Considerable local unpublished information on bilharziasis was obtained during the survey. Dr J. Pavars, head of the Schools Medical Service (school attendance in Ethiopia numbers 50 000), stated that he had not found bilharziasis among the schoolchildren of Addis Ababa (attendance about 7500) although he suspected much bilharziasis in the country in general. From various discussions it also appeared that the one case of haematobia infection reported from Lake Bishoftu was now generally considered to have contracted the disease while fishing in one of the affluents of the lake, because the lake itself is much frequented by Europeans, none of whom is reported to have acquired the disease.

Regarding the remainder of Shoa Province, the author was informed by Dr Therminé, Director of the Menelik II Hospital, that three or four mansoni cases had been found among students of the Agricultural School at Akaki, who had come from the surrounding Shoa highlands. Dr Therminé further stated that he had seen mansoni cases from Aduwa and the surrounding regions (Tigre) and about 40-50 mansoni cases from the Harar region. According to Dr F. B. Hylander, Chief Medical Adviser to the Ethiopian Ministry of Public Health, Lake Aramaya, near Harar, is thought to harbour infected snails although this has not been proved. The only case of *S. haematobia* infection known to Dr Therminé was that of a Dr Giovannona, who had acquired it in the west at Asosa, a town situated close to the Sudan border (latitude 10°N), in the Beni Shangul territory of Wallaga Province. This is of interest since, according to Dr Hylander, de Lotto, in 1940, had found no bilharziasis cases in Beni Shangul.

Professor G. Rizotti, Director of the Ras Desta Hospital, Addis Ababa, confirmed that bilharziasis mansoni cases from Tigre and from Eritrea had been admitted. He had also seen mansoni cases from the western provinces and had heard of haematobia cases in the regions adjacent to the Sudan, but the only haematobia cases seen by him personally had been Yemenites.

A doctor at Sheikh Osman Hospital in Aden, who had previously worked in Ethiopia, reported that he had seen mansoni cases from Aduwa and Harar, and also two haematobia cases who had contracted the disease in Ba 'adu (Bahdu) region, in a localized focus situated not very far from Gawani across the River Awash.

Information was received from the Adigrat Hospital that examination of the stools and urine of 100 out-patients had given negative results; that the drinking-water from three wells was free from schistosomes; and that specimens taken from the water of a river (in which the people wash hides and skins and in which cattle bathe) in the environment of the new hospital showed free-swimming cercariae forms of the parasite in abundance. Vector snails had not been found near this spot (investigations further upstream to locate snails had not been possible). The population was not using the river water for drinking purposes or for bathing.

Shoa Province. Addis Ababa, the capital of Ethiopia, is a city of 300 000 inhabitants, with a cool, agreeable climate. The population is a fluctuating mixture of numerous Ethiopian tribes with large European, Yemenite, and Hadhramaut communities. It is situated at an altitude of about 2800 m (9200 feet) on the high plateau of Shoa, which was once an outlying province but has become, in the past century, the centre of the country.

On account of the reported absence of bilharziasis among the schoolchildren of the capital, samples of excreta were taken not only from natives of the city but also from subjects who had moved from other parts of the country. All samples obtained in Shoa were negative for bilharziasis, although other intestinal helminth parasites were found to occur. Details concerning these examinations are given in the following paragraphs and in Table VI.

At the Menelik II secondary school, 33 urine samples and 31 stools were obtained from boys aged 14-21 years, who had been in Addis Ababa for periods varying from two months to ten years and who had originally come from the following places: 1 from Shoa Province (Akaki); 2 from Wallaga Province (1 from Nakamti); 5 from Kaffa Province (Jimma); 5 from Illubabor Province (Gore); 7 from Harar ; and 13 from Begemdir Province (Gondar).

At the Empress Menen girls' school the author examined 15 urine samples and 12 stools from pupils aged 12-19 years.

From inmates of Akaki prison aged between 15 and 40 years, 20 urine samples and 20 stools were obtained and examined. The regions of origin of these prisoners were as follows : 4 from Harar; 3 from Wallaga; 3 from Walliso; 2 from Gamu; 2 from Shoa; and 1 each from Sidamo, Hosseina, Sallale, Dessye, Gondar, and Somalia.

At the Bishoftu school 11 stools and 12 urine samples were collected from 7 girls and 5 boys aged 7-15 years, all of whom came from Bishoftu or the surrounding district.

It should, however, be stressed that these negative indications for various parts of the country do not necessarily represent the true state of affairs in these regions.

At the same time, field surveys were made for aquatic snails. In the environment of Addis Ababa, the River Hika was examined in a rocky spot containing algae, near the Hailé Selassié secondary school. No snails were found except *Burnupia*. Various affluents of the River Awash—the Akaki, the Dukam, and the Mojjo—were also examined. The River Akaki, a stream with steep muddy banks and graminaceous as well as broad-leaved vegetation, was found to contain *Bulinus* s.s. and *Gyraulus* near Addis Ababa, while further south, near Akaki village, it harboured numerous *Biomphalaria* in addition to *Bulinus* s.s., *Gyraulus*, and *Valvata*. The River Dukam was examined not far from Dukam village; it contained *Biomphalaria* of all sizes, as well as *Gyraulus*.

Examination of one of the beaches of the famous crater lakes of Bishoftu revealed a very squat type of *Bulinus*; the snails which were clinging to the underside of the rocks, were of all ages and were obviously breeding there. The River Mojjo, near Mojjo village, and the Awash, already a wide river at this point, did not contain snails at the places examined.

Arusi Province. The River Maki, an affluent of Lake Zwai, was surveyed for snails with negative results. The lake, a fine stretch of fresh water, at an altitude of 1850 m (6050 feet) is the northernmost of the Rift Valley lakes, a number of which are brackish or saline. In a shallow part of the lake, filled with vegetation, numerous specimens of a small type of *Bulinus* s.s., one young *Biomphalaria*, and small shells of *Gyraulus* were found, mostly attached to the underside of the leaves of aquatic plants. The detection of potential vectors corroborates similar findings by Orlandini [72] in the basins of several lakes further south.

Gojjam Province (Lake Tana region). The shores of Lake Tana were examined at various points near Bahrdar. A well-developed adult molluscan fauna was found and numerous specimens of *Biomphalaria*, two species of *Gyraulus*, and *Bulinus (Physopsis)*, *Lymnaea*, and *Bellamya (Viviparus)* were obtained, together with one unknown long-spired snail. The snails were mostly collected from floating leaves fallen from the surrounding trees. It was noted that a wind, strong enough to cause marked wave action, developed over the lake in the early afternoons, but the snails were full grown and abundant, and apparently undisturbed.

The Blue Nile, or Abbai, was examined about 3 km (2 miles) from the outlet of Lake Tana. At this point the river is about 300 m (1000 feet) wide with a fast current and sharp granite rocks. The snails recovered were all small, possibly immature, and consisted of numerous *Biomphalaria*, *Gyraulus*, *Bulinus (Physopsis)*, and *Lymnaea*, as in the lake, with the addition of *Bulinus* s.s., *Melanoides*, and *Valvata*.

The snails from this region closely resembled the Egyptian and Sudanese types, except for the unidentified long-spired snail and the *Bulinus (Physopsis)*; the latter does not occur in Egypt and has not been reported from the Blue Nile in the Sudan, except by Schwarz (see pages 58, 102).

About 35 km (22 miles) from the outlet, the river leaves the plateau and makes a drop of 45 m (150 feet) at the Tis Åbbai falls, to continue its course in a deep canyon. Just below the falls, the ravine narrows to a width of 1.5-2.0 m (about 3-6 feet). Whether these conditions represent an actual obstacle to the spread of *Bulinus (Physopsis)* downstream has not been ascertained.

In view of the reports of autochthonous *S. haematobium* from the region (Ganora [34]) and from Lake Tana (L'Abbate [55]), the author expected to find positive urines in the sample surveys. This, however, was not the case. At the elementary school, Bahrdar, 20 urine samples were obtained from 15 boys and 2 girls between the ages of 9 and 16 years and from 3 teachers aged 21-45 years, all natives of the region; these were, without exception, negative for *S. haematobium*. Only 17 stools were obtained; of these 10 (59 %) showed, most unexpectedly, ova of *S. mansoni*, distributed among 7 boys, 1 girl, and 2 teachers.

At a nearby military camp, 21 men between the ages of 20 and 40 years, who had been stationed at Bahrdar for the past two years, as well as their captain, were examined with similar results. The 21 urine samples proved

TABLE V. PLACE OF ORIGIN OF MILITARY PERSONNEL AT BAHRDAR CAMP, LAKE TANA, ETHIOPIA

S. mansoni		Total number examined	Origin	
positive	negative		town	region
9	7	16	Gondar	north of Lake Tana, Amhara (Begemdir)
1		1	Debra* Tabor	east of Lake Tana, Amhara (Begemdir)
1		1	Debra* Markos	south of Lake Tana, Gojjam
	1	1	Nakamti	south-west of Lake Tana, Wallaga
	1	1	Hoazien	north-east of Lake Tana, Tigre
	1	1	Aksum	,,
1		1	Adigrat	,,
12	10	22		

* "Debra" = town

negative for *S. haematobium*, while 12 out of 22 stools (55%) were positive for *S. mansoni*. It was learned that the men quite commonly used the lake for bathing. The officer, a captain from Adigrat, who had previously served in Eritrea, Egypt, and Libya, was one of the infected. The places of origin of the soldiers and the distribution of infection among them are given in Table V.

The hotel servant, a local man, also proved to be infected with *S. mansoni*, while the Governor, the hotel proprietor's wife, and the family of the captain, were found to be free from bilharziasis. Infestation with various intestinal helminths was heavy in all groups of persons examined at Bahrdar.

The infection of the local inhabitants, mainly schoolchildren, with *S. mansoni*, as well as the closely similar infection-rate in adults who had been resident in the region for some time, are evidence of a local focus of infection. There is no reason to suppose that conditions differ in other

TABLE VI. URINE AND STOOL * EXAMINATIONS IN ETHIOPIA

Locality	Persons examined			For *S. haematobium*		For *S. mansoni*	
	type	age (years)	sex	examined	positive	examined	positive
Shoa Province							
Addis Ababa:							
Menelik secondary school	pupils	14-21	♂	33	0	31	0
Empress Menen school	pupils	12-19	♀	15	0	12	0
Akaki: prison	inmates	15-40	♂	20	0	20	0
Bishoftu: school	pupils	7-15	♂-♀	12	0	11	0
Gojjam Province							
Bahrdar:	miscellaneous	7-31	♂-♀	1	0	5	1
elementary school	pupils and staff	9-45	♂-♀	20	0	17	10
military camp	men and officers	20-40	♂	21	0	22	12
Harar Province							
Diredawa: hospitals	random patients		♂-♀	4	0	5	0
Harar: hospitals	random patients		♂-♀	12	0	16	1
			Total	138	0	139	24

The secondary school pupils, prisoners, and soldiers came from various parts of the country.

* Other intestinal helminths found among the 139 stools examined were: 49 *Ascaris*, 30 *Trichocephalus*, 20 *Strongyloides*, 14 *Ankylostoma*, 11 *Hymenolepis*, 4 *Trichostrongylus*, 1 *Oxyuris*. The heaviest incidences, both among the local inhabitants and the military, were also at Bahrdar.

TABLE VII. FRESHWATER GASTROPOD MOLLUSCS COLLECTED IN ETHIOPIA

Serial No.	Place of collection	Description	Species
	Shoa Province		
14	Akaki river, Addis Ababa	muddy banks, broad-leaved and graminaceous vegetation	*Bulinus (Bulinus)* sp. *Gyraulus* (*Anisus*) *natalensis* Krauss *
15	Hika river, near Addis Ababa	rocky, algae	*Burnupia* (? *abyssinica* Jickeli) *
7	Akaki river, near Akaki	steep muddy banks, graminaceous and broad-leaved vegetation	*Biomphalaria* sp. *Gyraulus costulatus* Krauss * *Bulinus (Bulinus)* sp. *Valvata* sp.
8	Dukam river, near Dukam	—	*Biomphalaria* sp. *Gyraulus costulatus* Krauss
9	Bishoftu, lake-shore near Swedish settlement	stones and rocks	*Bulinus (Bulinus)* sp. **
	Arussi Province		
10	Lake Zwai	shallow shore with graminaceous vegetation	*Bulinus (Bulinus)* sp. *Gyraulus* (*Anisus*) *natalensis* *Biomphalaria* sp.
	Gojjam Province		
11	Lake Tana, near Bahrdar village	pebbly shore, waves in the afternoon	*Bulinus (Physopsis)* sp. *Biomphalaria* sp. ** *Gyraulus costulatus* *Gyraulus* (*Anisus*) *natalensis* *Lymnaea natalensis* †
12	Blue Nile, 3 km from outlet	swift current, sharp rocks	*Biomphalaria* sp.** *Gyraulus costulatus* *Bulinus (Bulinus)* sp. ** *Bulinus (Physopsis)* sp. ** *Lymnaea natalensis* *Melanoides tuberculata* *Valvata* sp.
13	Lake Tana, near Hotel Bahrdar	pebbly shore, waves in the afternoon	*Biomphalaria* sp. *Bulinus (Physopsis)* sp. *Lymnaea natalensis* *Bellamya* (*Viviparus*) *unicolor*
	Harar Province		
16	Lake Adilé	grasses, waves	*Bulinus (Bulinus)* sp.
17	Lake Aramaya	grasses, waves	*Bulinus (Bulinus)* sp.
18	Pond, near Aramaya village	stagnant, algae	*Bulinus (Bulinus)* sp. ** *Lymnaea natalensis*

*** Identification by Mandahl-Barth (personal communication). Note that *Gyraulus costulatus* is a synonym of " *Planorbis* " *gibbonsi*, which is the name used by Blair (personal communication), and that the shell of this snail hardly differs from the Egyptian *Gyraulus* (*Planorbis*) *mareoticus*.**

**** See Fig. 10, and section entitled Malacological Notes, page 93.**

† *Lymnaea natalensis* Krauss, identification by Mandahl-Barth (personal communication); this South African species, which in its typical form is smaller than the common large African *Lymnaea* (*L. cailliaudi*) is now generally considered synonymous with it. Note that the "type" of *L. cailliaudi* was collected by Bourguignat from Lake Tana.

NOTE:

(1) Mandahl-Barth (personal communication) considers the *Biomphalaria* samples sent from the Ethiopian region to be *B. rüppellii* Dunker, and he ranges the various types of *Bulinus* s.s. from

localities situated on the well-populated shores of Lake Tana, and the author believes the region to be eminently suitable for the propagation of the disease. Although there is little doubt that *S. mansoni* was acquired locally by the military personnel, the possibility cannot be excluded that the infection might have been pre-existent in some of them. The captain had previously lived in endemic regions, and the cities of origin of the other infected men could be considered as possibly suspect; both Gondar, the old capital of the Amharic kings, and Debra Tabor (" debra ", " addi " and " adi " = town), a later capital, are situated about 30 km (19 miles) from Lake Tana, and extensive movements of cosmopolitan armies took place in these regions during the Second World War.

Harar Province. The drinking-water sources at Diredawa, consisting of various streamlets seeping out of sandy gravels, were examined but no snails were found.

At the hospital, only 4 urine samples and 5 stools could be obtained; these were found negative for bilharziasis.

Near the Diredawa-Harar road, at Lake Adilé, a water collection with strongly-lapping waves and a vegetation consisting of various grasses, a large number of *Bulinus* snails proper of a small ovoid type were found. As previously mentioned, Lake Aramaya, about 17 km (10.5 miles) from Harar, is suspected of harbouring infected snails, although this has not been proved. In view of the well-known endemicity of bilharziasis mansoni, the suspect snail is evidently *Biomphalaria.* It should be noted that the occurrence of *S. haematobium* is uncertain, Mennona & Modugno [69] reporting its appearance as being exceptional among the Harari population. In Lake Aramaya, *Bulinus* s.s. were also recovered from a habitat similar to that encountered in Lake Adilé. A stagnant pond near Aramaya village, with muddy banks and algae, contained large specimens of *Lymnaea natalensis* and of *Bulinus* proper.

No snails were found in the waters of Harar. Random urine samples and stools were obtained from a number of patients at the free and at the paying hospitals. The 12 urine samples examined all proved negative, while out of 16 stools examined, 1 contained ova of *S. mansoni.* This positive case had come from Aramaya four years previously.

Results of the urine and stool examinations are summarized in Table VI and a list of the freshwater molluscs collected is given in Table VII.

Note to Table VII (continued)

that region (Serial No. 9, 12, and 16 from Ethiopia, as well as other samples from Eritrea and Yemen) under *B. sericinus* Jickeli. As for *Bulinus (Physopsis,)* he designates the sample (Serial No. 11) from Lake Tana *Bulinus globosus* Morelet.

(2) Blair (personal communication) considers one of the *Biomphalaria* samples (Serial No. 7) as resembling *B. arabica* and another (Serial No. 13) as " close to *boissyi* ", while he places two of the samples of *Bulinus* s.s. (Serial No. 9 and 16) under *truncatus.* A specimen of the Lake Tana sample of *Bulinus (Physopsis)* (Serial No. 11) is described as intermediate between *nasutus* and *africanus* but closer to *africanus.*

(3) See also section entitled Malacological Notes, page 93.

Discussion

Although records for this large area are few and suffer, on the whole, from a deplorable absence of case-histories, it seems already evident that bilharziasis of both types is established principally in the northern part of the Ethiopian highlands, a region which, incidentally, coincides with the older parts of the Ethiopian Empire and which is inhabited by the Tigreans and Amharas. As far as can be judged from the isolated reports available for the remainder of the country, both forms of bilharziasis also occur in the western borderlands of central Ethiopia, among the Gallas and the Nilotic population. A separate localized focus of *S. mansoni* exists in mountainous Harar, in the east. In the plains of the Danakil Desert, bilharziasis has not been reported. The disease does not seem important in the centre and appears to be absent in the south—namely, in the desert and semi-desert regions of the south-east lying in the Somali arid zone—as well as in the more lush zones of the south-west.

Ricci [78] states that, in Ethiopia, the biological conditions prerequisite for the spread of *S. haematobium* do not seem to exist except in Amhara and Tigre, nor favourable conditions for the development of *S. mansoni*, except in Tigre and Harar. In the author's opinion, this statement needs to be modified. Amhara must also be included in the zone considered suitable for *S. mansoni*, since the author has shown that apparently excellent conditions for the development of *S. mansoni* infection exist at Lake Tana (southern Amhara or Gojjam) while cases have also been reported from Zerima (northern Amhara or Begemdir). The impression was gained that favourable conditions for both forms of the disease probably exist in the western zone also. Although Gore, a town lying in the centre of the highest rainfall zone, was not visited, the author finds it difficult to understand why conditions for the development of the vector snails are not suitable there, as maintained by Nägelsbach.[71]

In general, the author believes that conditions are favourable for the spread of bilharziasis in wider areas than are at present either incriminated or actually stricken. It is also felt that the prophecies of Zavattari [103] with regard to the ultimate propagation of bilharziasis are being rapidly fulfilled and that the conditions arising from the Second World War are duplicating and intensifying those he described for the earlier Italo-Ethiopian campaign. The presence of large numbers of Yemenites in various parts of the country was also noted; these doubtless represent a potential danger with regard to the dissemination of bilharziasis.

At the present stage, the true importance of the disease cannot be assessed; it will, however, increase parallel with progress in the economic development of the country in connexion with the establishment of irrigation works and the construction of roads and ensuing intensification of traffic, as well as with the increased concentration and density of population.

After the erection of the projected Lake Tana dam, for example, the shallower beaches of the future lake will probably afford even better conditions for snail life, while the emigration of the population of the flooded areas to other parts of the country may contribute to the further propagation of the disease.

Apart from the question of the extent and gravity of human incidence, more information must also be obtained concerning the distribution of suspect mollusc vectors of the disease. It seems fairly safe to assume that all types of *Biomphalaria* will prove to be vectors. Elucidation of the respective roles of the two subgenera of *Bulinus* s.l. will be of special interest, since *Bulinus (Physopsis)*, the normal vector of *S. haematobium* in equatorial and Southern Africa, occurs much farther north in Ethiopia than it does in the adjacent Sudan, while the vector role of *Bulinus* s.s. in the Ethiopian highlands is as yet problematic (see page 17). The Italian authors have assumed *Bulinus* s.s. to be the vector, apparently from analogy with the countries of North Africa and the Middle East, and have not noted the presence of *Bulinus (Physopsis)* in the northern highlands. It should, however, be borne in mind that the tropical and South African forms of *Bulinus* s.s. do not seem to act as vectors, while doubt can also be cast on the vector capacity of the Eritrean type.

SOMALIA

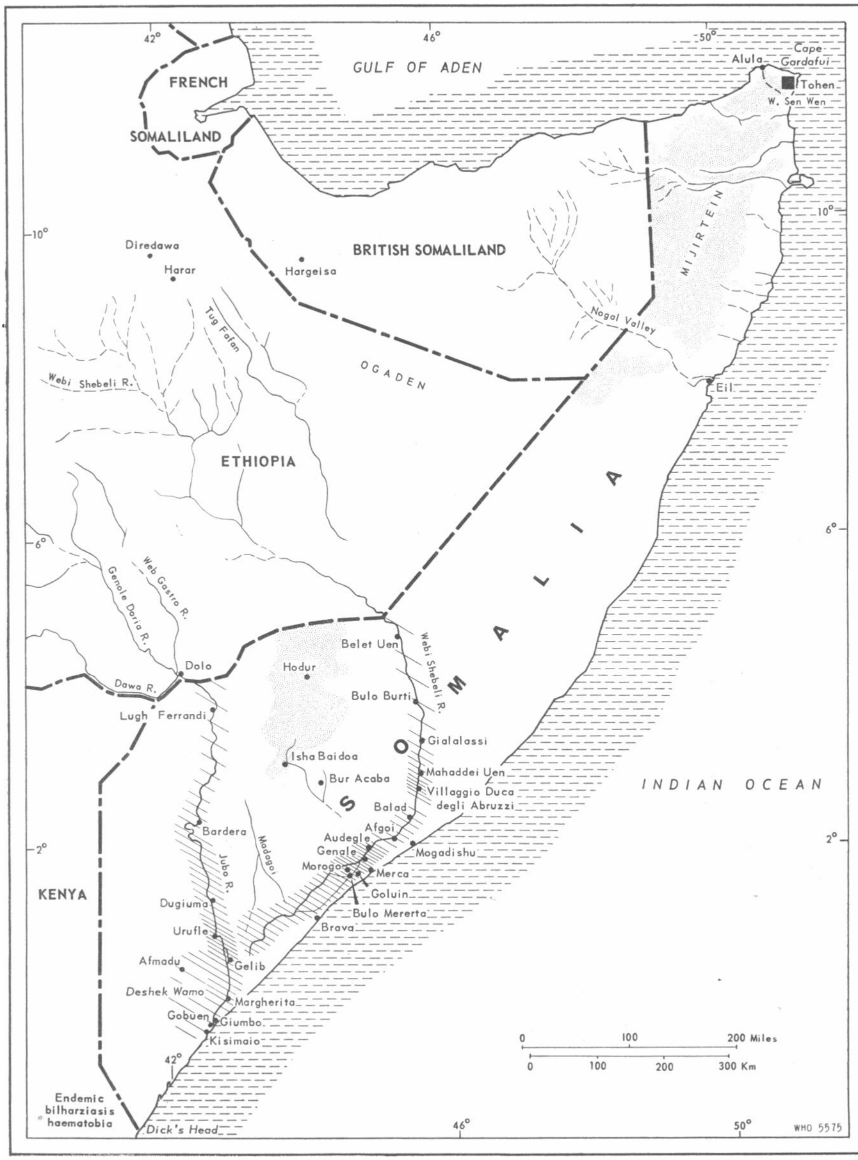
General Description

Somalia (see Fig. 4) is formed by a large strip of territory varying from 150 km to 500 km (90-310 miles) in width and following the coastline of the Indian Ocean for a length of about 2000 km (1240 miles) from Cape Gardafui, on the easternmost horn of Africa (latitude 12°N) in the north-east, to Dick's Head (at about latitude 2°S) in the south-west. The country has also 250 km (155 miles) of northern coastline on the Gulf of Aden. Its borders towards British Somaliland and Kenya are largely formed by the 49th and 41st meridians, respectively, while its frontier with Ethiopia is not definitely demarcated.

Only the very northernmost part of the country is characterized by a highland region, continuing from British Somaliland at altitudes of 1000 m (3300 feet) or above. The greater part of the country is below 500 m (1650 feet), the lowlands being a narrow coastal strip in the north and widening in the south. In this southern part there is, however, an outrunning tongue of the Ethiopian massif that gives rise to higher terrain between the two main river valleys in the region of Oddur (Hodur).

Southern Somalia has two great rivers draining from the Ethiopian highlands: the Juba in the extreme west, which runs from north to south and flows into the Indian Ocean a little south of the Equator, and the

FIG. 4. SOMALIA



S. haematobium (vector *Bulinus* (*Physopsis*) *abyssinicus*):

■ focus

▨ moderate to heavy areas

░ 1000-2000 m (3300-6600 feet)

Webi Shebeli further east, which also flows due south almost to the coast and then turns to the south-west, flowing parallel to the coastline and separated from it by a low ridge. In its lower course, the river becomes absorbed by irrigation schemes and just fails to reach either the Juba or the sea.

Somalia covers an area of about 500 000 km² (190 000 square miles) and lies, together with the adjacent territories, in the so-called " Somali arid region ", which is a semi-desert and steppe zone. However, wide belts of open forest follow the courses of the two main rivers and also skirt the Nogal Valley and a few other valley (" wadi ") systems in the northern highlands. The territory may be divided into the following categories:

		Km²	*Square miles (approximately)*
Permanent pastures and brush		256 500	99 000
Forests		71 500	27 600
Agricultural lands	— irrigated	3 000	1 160
	dependent on rainfall	5 000	1 950
	usable, if necessary	328 000	127 000
Wastelands	— rivers	2 000	800
	unusable	17 000	6 600

The monsoonal double rainfall increases in quantity towards the south-west, amounting to about 500 mm (20 inches) annually in the Juba area. The great spring rains (" gu ") occur in the period from April to July, beginning and ending earlier in the interior. The little rains (" der ") fall in October-November.

The population, which consists of various Somali tribes, amounted to one million in 1931. Mogadishu, the capital, has a population of 55 000.

The principal occupation of the people is cattle-rearing and agriculture. In southern Somalia, the natives inhabit and cultivate the country near the banks of the Webi Shebeli and Juba rivers. Italian plantations, with a cultivation of some 20 000 hectares (ha) (49 500 acres), are situated mostly on the middle course of the Webi Shebeli (regions of Merca, Genale, Villaggio Duca degli Abruzzi, etc.) but also along the Juba. The crops are mainly cotton, millet, maize, sesame, bananas, and other fruit; coco-nuts are also planted extensively. In the north, the Mijirteins rear camel and sheep.

In former years the country was heavily subsidized; in the budget for 1935-36, the revenue proper of the colony amounted to 23 million pounds sterling and the contribution of the Italian State to 47 million; the civil expenditure alone amounted to 45 million. As the Italian mandate is due to expire in 1960, various development projects are held in suspense. Foremost among these is the canal planned to connect the Juba, a river with a sufficient and stable water-flow, to the Webi Shebeli, which has little water in winter. A large tract of land along the new canal would also be brought under cultivation by this project.

Geographical Distribution of Bilharziasis

Review of available data

S. haematobium. According to Zavattari,[103] the first reports of vesical bilharziasis from Italian Somaliland (Somalia) were made by Croveri;[23] according to Ricci,[78] they were made by Corrado[20] when, in 1925, he stated that the disease was rare. The first data on the real incidence of this helminthic disease were given in 1927 by Basile,[15] who claimed a moderate dissemination along the middle course of the River Webi Shebeli, and by Veneroni[93-95] who, in 1926, 1927, and 1928, reported that the disease was prevalent in the lower Webi Shebeli valley, that is, in the part parallel to the coast. The latter author found 30% of the population, especially the younger age-groups, infected with bilharziasis, in the regions running parallel to the river from Morogo (in the east) to Balli (in the west), where the river dries up.

The combined information from a number of authors points to the lower Webi Shebeli as a classical zone of endemicity. Thus Decina, Tedeschi & Ruffino,[29] in 1933, found cases in the upper part of the lower Webi Shebeli. Bartolucci,[14] writing about the Brava region in 1933, stated that " schistosomiasis is found only in the hinterland " but that " the percentage of infected persons there is very high ",[a] although he himself had seen only a few clinical manifestations. He also drew attention to the major importance, in the transmission of the disease, of the various artificial and natural depressions which contain water for a greater or lesser part of the year. Dalri,[26] in 1933 and 1934, wrote from Genale that bilharziasis infection reached 80% in the Giddu region (downstream from Genale), while in the Genale concession proper it was prevalent only in the riverain population; he also reported that the infection was common among the Deghèl. Croveri,[24] in 1934, reported that the disease was fairly prevalent, especially on the coast. He considered the primary cause of propagation to be the Moslem practice of ablutions before prayer and suggested that the molluscan intermediate host might well be present in the mosque basins. Zavattari,[103] in 1938, observed the presence of the disease in the regions of Genale, Bulo Mererta, and Goluin; this is also referred to by Moise.[70]

With regard to the regions along the higher reaches of the Webi Shebeli, Basile's report has been substantiated by a number of authors writing mostly from Villaggio Duca degli Abruzzi, locally referred to as Villaggio or Villabruzzi, the centre of the important Italo-Somali Agricultural Society (SAIS).

Mennona,[67] in 1929, found bilharziasis cases along the upper course of the river, both in the Alto Benadir district of the lower Webi Shebeli region, and also away from the river in the border region. He described

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[a] " Diffusa solamente al retroterra ritengo però altissima la percentuale degli infestati nella popolazione."

the disease as being benign and as becoming naturally extinct after a few years. All cases personally seen were boys or youths.

He further stated that the children, in particular, love to wade and bathe in the water for a long time. He never found " *Bulinus* " and is the only author to have reported the existence of " *Planorbis* " (*Biomphalaria*) which is doubted by Zavattari who criticizes Mennona's rough sketches, not without justification.[103]

Mattei,[66] in 1931, reported four cases from the middle Scidlè region (around Mahaddei Uen), one of whom, however, was an Arab who had presumably contracted his infection in the Yemen. Mattei was also able to find *Bulinus* (*Physopsis*) in the various more or less permanent water collections, around which the population gathers to drink, to wash, and to bathe themselves and their animals. These water collections are described as having the greatest importance in the propagation of various parasitic diseases in view of the indiscriminate deposition of excreta in their vicinity. They are : the "Uar", an artificial pond which will hold water for from three to four months during the dry season ; the " Balli ", a natural depression which will collect and hold water for 50-60 days ; the " Bio Ala ", a depression near the river, and fed by it, which may hold water for from two to three weeks ; and the " Ghel ", a deeper depression of similar nature which may hold water throughout the dry season.

Moise,[70] in 1938, reported that, in the period from 1932-37, he had had occasion to see 60 haematobia cases at the A. Cecchi Hospital at Villabruzzi, some slight, but others (old cases) severe and showing serious urological and other complications. The patients were preponderantly males and settlers on the estate. He traced, as the probable source of infection, several secondary irrigation streams filled with almost stagnant water and a dense aquatic vegetation, and collected from these channels " numerous molluscs of the genus *Physopsis* " which he considered to be " evidently the intermediate hosts of the helminth ".[a] He stated that these snails, "although they present a number of similar characteristics, can be classified neither with the *Bulinus* of Egypt nor with *Physopsis globosa* of Equatorial Africa ".[b] He suspected that the disease was also prevalent among the natives of the bush and forest zones away from the river, who did not present themselves at the hospital because they lacked the opportunities of the agricultural workers of the estate, who lived in the vicinity and often reported sick in order to be relieved from work. He thought that an epidemiological survey in tracts adjoining torrents and the more or less temporary seepage-water or other stagnant water collections would be of great interest, believing that the scarcity of available water, coupled with the habits of the population, furnished favourable conditions for the propagation of the disease. He

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a " ... numerosi molluschi del genere *Physopsis*, evidentemente gli ospiti intermedi dell'elminta."

b " Pur presentando dei caratteri molto simili, essi non sono da classificarsi nè con il *Bulinus* dell'Egitto nè con la *Physopsis globosa* dell'Africa Equatoriale."

especially commented on the great need of the Somali to keep his person clean, and on his habit of making use of any water collection for his ablutions.

Lipparoni,[58] in 1950, reported a much increased incidence among the agricultural workers of the Villabruzzi region which he attributed, in part, to repercussions arising from the war and post-war periods. He stated that the spread of bilharziasis was assuming an alarming rate and that the actual conditions were much more severe than had hitherto been supposed, even though the disease was as yet relatively benign and was taken lightly by the natives. Haematuria had already been differentiated by the population and was called " kadi-dik " (bloody urine) in the local Somali dialect. Lipparoni also reported similar conditions for Afgoi, lower down on the Webi Shebeli. At Villabruzzi, both the river banks and the irrigation streams of the SAIS are described as a source of infection and it is stated that the luxuriant vegetation along their banks harbours numerous bulinid snails, which in a later publication [59] were determined as *Bulinus abyssinicus*, a species belonging to the subgenus *Physopsis*. He further reported that the inhabitants of villages situated 40-50 km (25-31 miles) away from the river or the irrigation canals, who depended entirely on the " uar " for bathing and for their water-supply, were infected with *S. haematobium* to an equal extent, a fact of evident epidemiological importance. He assumed that the various seasonal rain-water and seepage-water ponds also contained vector snails (see Mattei [66]), and that they had become new transmission foci through patients who had previously acquired their infection in the river or in the canals.

Systematic urine examinations of all in- and out-patients at the A. Cecchi Hospital in Villabruzzi over a period of two and a half years revealed a monthly average of 40 haematobia cases, of which, however, a considerable percentage were relapses. A haematuria census was taken by Lipparoni in a zone 40-50 km (25-31 miles) wide and extending for about 80 km (50 miles) along the Webi Shebeli from Mahaddei Uen to Balad. This survey was based on the assumption that every case of haematuria, in that particular environment, represented a case of bilharziasis ; a microscopic check was possible in one third of the haematuria cases found, and the presence of bilharzia ova in all instances was confirmed. A total of 520 haematuria cases was obtained from numerous villages during a period of two months. From this it was estimated that, at the completion of the survey, 1000 cases showing the clinical manifestations of bilharziasis would have been obtained from the entire area, which corresponds to an incidence of 3.33%, while it was thought that systematic laboratory research would result in a larger percentage of infection. Lipparoni observed that men are infected with bilharziasis more than women, the agricultural population more than the pastoral, and, contrary to Mennona's view,[67] that adults are smitten more often than children.

When available, Fouadin or Stibional-Anthiomaline were administered to patients at the usual dosages. Otherwise, the treatment consisted of a series of 16 intravenous injections of a 1% solution of tartar emetic, given at 3-day intervals and progressively graded, for an adult, as follows : 3 ml, 6 ml, 9 ml, and 12 ml, the latter dosage being maintained up to the 16th injection. Lipparoni, however, deplores the scarcity of therapeutic drugs and the lack of constancy shown by the Somali patients in attending for treatment, and advocates mass treatment and persistent propaganda to improve the habits and hygienic knowledge of the Somalis.

Conditions along the River Juba are equally suitable for bilharziasis and a parallel situation has developed, although the disease was not reported until a little later. It was only in 1937 that Guidetti [43] declared the disease to be widespread in the lower Juba valley. Diamanti [30] reported its existence in Bardera, on the middle Juba, in 1939. Lipparoni,[58] in 1950, pointed out that the disease had been increasing in incidence and severity on the Juba as on the Webi Shebeli. It should be noted that Zavattari,[103] in 1938, had failed to find bilharziasis in the upper Juba basin, that is on the River Dawa.

Bilharziasis has also been reported beyond the two river valleys. Decina, Tedeschi & Ruffino,[29] in 1933, found numerous cases in the region of Oddur (Hodur), which is situated on the higher terrain between the two rivers (Upper Juba Province). Rossi,[80] in 1939, reported the disease from Tohen in the extreme north-east of Somalia, giving as the probable focus of infection Wadi Sen Wen, a valley which contains water most of the year and which borders on Wadi Tohen, running to the Indian Ocean about 10 km (6 miles) south of Cape Gardafui.

S. mansoni. Most of the above-mentioned authors specifically mention their failure to find *S. mansoni* in Somalia. Although Basile [15] in 1927, diagnosed two cases in Arabs on the middle Webi Shebeli, which he tends to consider as autochthonous, it seems fairly certain that all cases of *S. mansoni* ever recorded from the territory have been introduced from outside. In 1936, two cases were recorded in Mogadishu, one by Bacchelli,[11] who reported a case of certain importation from Yemen, the other by Mariani,[62] who found a case in a man from India. Lipparoni,[58] in 1950, mentioned a case in a coloured soldier of the British Army, a man from Tanganyika living only temporarily in Villabruzzi, who must have acquired his infection abroad. Zavattari,[103] in 1938, commented on the absence of bilharziasis mansoni and wondered whether environmental conditions are favourable for the establishment of this disease, which certainly must have been introduced more than once, in view of the fact that " exchanges between Arabia and Somalia are ancient, constant and frequent ".[a]

No conclusive report of the occurrence of *Biomphalaria* in the territory exists.

[a] " ... gli scambi fra Somalia e Arabia sono antichi, costanti e frequenti... "

Survey

The data recorded during 1947-49 in the hospital at Mogadishu, which receives patients from various parts of the country, are given in Table VIII. Diagnosis of out-patients was, in the main, clinical, while that of hospitalized cases was performed microscopically; all, however, received treatment.

TABLE VIII. BILHARZIASIS HAEMATOBIA CASES IN MOGADISHU, SOMALIA, 1947-49

Year	Diagnosis	
	clinical	microscopic
1947	568	79
1948	557	57
1949	663	70

In various endemic areas, mainly on the Webi Shebeli but also from the Juba, a total of 1206 cases were diagnosed microscopically during the period June 1950 to December 1951. These are listed according to their origin in Table IX, while an analysis according to age, sex, and occupation is given in Table X.

TABLE IX. ORIGIN OF BILHARZIASIS HAEMATOBIA CASES, FROM HOSPITAL RECORDS IN ENDEMIC AREAS IN SOMALIA, 1950-51

Location of hospitals and dispensaries	Number of cases
Villaggio Duca degli Abruzzi	592
Afgoi, Barire, Mererei, Uanle	100
Mogadishu	142
Merca, Genale	299
Kisimayo	73
Total	1 206

It is seen from Table X that all ages from 4 to 75 years were represented, with a marked preponderance of the age-groups between 11 and 30 years (70%) and of the agricultural and pastoral population (67%). The proportion of females was small (2.7%). The duration of the symptoms was recorded at the time of examination and was found to correspond to an average of about three years per person.

TABLE X. AGE, SEX, AND OCCUPATION OF BILHARZIASIS HAEMATOBIA CASES FROM HOSPITAL RECORDS IN ENDEMIC AREAS IN SOMALIA, 1950-51

Age-group (years)	Number	Percentage	Females (domestic occupation)	Males			
				agricultural and pastoral population	pupils	artisan and merchant population	unspecified
4-10	100	8	3	18	45	1	33
11-20	460	38	14	293	75	66	12
21-30	381	32	12	286	—	75	8
31-40	189	16	2	152	—	33	2
41-75	76	6	1	54	—	19	2
Total	1 206	100	32 (2.7%)	803 (66.6%)	120 (10%)	194 (16%)	57 (4.7%)

In the non-endemic areas, recorded bilharziasis cases in 1950-51 were few or absent, as is shown in Table XI.

TABLE XI. BILHARZIASIS HAEMATOBIA CASES, FROM HOSPITAL RECORDS IN NON-ENDEMIC AREAS IN SOMALIA, 1950-51

Province	Town	Number of cases
Mudugh	Obbia	1
Upper Juba	Isha Baidoa'	2
	Lugh Ferrandi	4
Mijirtein	Bender Kassim	0
	Alula	0

General incidence in the country, as estimated by the health authorities, is presented schematically in Fig. 4 (see page 34). It appears that the heaviest incidences occur on the Webi Shebeli (in the region of Villabruzzi and Genale), and on the Juba, from Dugiuma down to Gobuen. The disease exists, but is difficult to assess, among the nomad tribes living on the terminal stretch of the Webi Shebeli from Bulo Messer to Balli Uen and Balli Ier (Big and Little Balli). A moderate incidence is found among the nomad Deshek Wamo, living west of the Juba, as well as in the region of Afmadu.

Bilharziasis has been reported from the inland hills of Upper Juba Province, which separate the upper courses of the two rivers—for example, from the Ethiopian border and from the regions of Hodur and Isha Baidoa. A survey in the Baidoa region was made by Dr Bacchelli (personal communication, 1952). In Bur Acaba and Isha Baidoa, towns lying respectively 180 km (112 miles) and 250 km (155 miles) north-west of Mogadishu, he examined numerous specimens of urine and faeces for bilharziasis, with negative results, and found that the cases reported from that area had originated from the middle Webi Shebeli, in particular from Audegle, Coriale, and Genale. An examination of the torrent draining these parts, from its source to the point where its waters dry up, produced no molluscs.

Villaggio Duca degli Abruzzi. The Webi Shebeli River near Balad did not yield any molluscs. A little further north, *Bulinus (Physopsis)*, *Lanistes*, and large *Pila (Ampullaria)* were found in the remnants of a rain-water collection with a mud bottom and a vegetation of water-lilies.

The irrigation streams of Villaggio seemed remarkably like those of Egypt. A canal near the entrance to the sugar factory was examined but only *Bulinus (Pyrgophysa) forskalii* was found.

At the A. Cecchi hospital at Villaggio, it was learnt from the Director, Dr E. Lipparoni, that Nilodin had been recently tried out, a total dose of 125 mg per kg of body-weight being spread over three days. Contrary to his expectations, cure had been observed in only 32% of the patients, a certain number of whom relapsed after one month. Dr Lipparoni had also examined a group of 83 schoolchildren at Villabruzzi, of whom 12 (14%) were found to be infected with bilharziasis.

TABLE XII. URINE AND STOOL* EXAMINATIONS IN SOMALIA

Locality	Persons examined	For *S. haematobium*			For *S. mansoni*	
		examined	positive		examined	positive
			no.	%		
Webi Shebeli Valley						
Villabruzzi: primary school	pupils	20	7	35	20	0
Genale: random	population	33	18	55		
Juba Valley						
Gelib: school	pupils	30	6	20		
Urufle: random	population	20	11	55	8	0
Total		103	42	41	28	0

* Other intestinal parasites found among the 28 stools examined were: 12 *Ankylostoma*, 14 *Ascaris*, and 3 *Trichocephalus*.

TABLE XIII. FRESHWATER GASTROPOD MOLLUSCS COLLECTED IN SOMALIA

Serial No.	Place of collection	Description	Species
	Webi Shebeli Valley		
34	Mogadishu-Villabruzzi road, km 40	Remnant rainwater pools, mud bottom, thorny banks, *Nymphea*	*Bulinus (Physopsis) abyssinicus**,** *Lanistes* sp. † *Pila (Ampullaria) ovata*
35	Villaggio Duca degli Abruzzi	Channel near sugar factory; muddy, graminaceous vegetation	*Bulinus forskalii*
36	Audegle (65 km west of Mogadishu)	Remnant rainwater pools	*Bulinus forskalii* *Lanistes* sp. *Syncera aurifera* Preston ††
37a	Genale (88 km west of Mogadishu)	irrigation streams: at Bufo farm, 1 ½ m (5 feet) wide, 70 cm (28 inches) deep, muddy banks, *Panicum* at State model farm, 6 m (20 feet) wide and 2 m (7 feet) deep	*Bulinus (Physopsis) abyssinicus* *Pila (Ampullaria) ovata* *Cleopatra bulimoides*
37b	Genale	various streams taking from Webi Shebeli above dam	*Bulinus (Physopsis) abyssinicus*
38	Genale	Webi Shebeli river, below dam, muddy, graminaceous vegetation	*Syncera aurifera* Preston *Succinea* sp. §
	Juba Valley		
39a	Margherita	marsh near river Juba	*Cleopatra bulimoides*
39b	Urufle	Juba river, steep-banked, silty, 80 m (about 90 yards) wide, few weeds ; from bottom of boat	*Syncera aurifera* Preston
		stranded on fields	*Pila (Ampullaria) ovata*

* See Fig. 10, section entitled Malacological Notes, page 93.

** Specimens of *Bulinus (Physopsis)* from this location have been identified as *Physopsis africana* by Blair (personal communication). Mandahl-Barth (personal communication), like Lipparoni,[59] designates it *Bulinus abyssinicus* Bourguignat. The shells seem to be of a type intermediate between the two subgenera, the spire resembling certain types of *Bulinus* s.s. while the truncated columella resembles *Bulinus (Physopsis)*, as known from other locations. Analogous observations were made by Moise[70] (see pages 37-38).

† The *Lanistes* shells collected in Somalia seem indistinguishable from *L. bolteni* of Egypt; Mandahl-Barth (personal communication) however prefers *L. carinatus*.

†† Identification by Mandahl-Barth (personal communication)

§ These shells, which look remarkably like a *Lymnaea* sp., were identified by Mandahl-Barth (personal communication) as *Succinea*, probably *aethiopica* Bourguignat.

At the local school, urine samples and stools from 20 boys aged from 7 to 14 were examined: 7 urines (35%) were positive for *S. haematobium*; the stools were all negative for bilharziasis.

Lower Webi Shebeli and Juba. Various waters within reach of the road skirting the lower Webi Shebeli were examined. At Genale, where the river is about 60 m (200 feet) wide, a big dam has been built across the river and various streams originate at this point. It was learnt that about three weeks later the river would be dry. *Bulinus (Physopsis)* was found in some of the streams originating above the dam. Streams on nearby farms were also examined and yielded *Cleopatra* and *Pila (Ampullaria)*. The resemblance of the aquatic flora and fauna to that encountered in Egypt was again noted. Below the dam, in a muddy spot of the river overgrown with grasses, the author found *Succinea* and a small amnicolid, *Syncera*. In Genale, 33 urine specimens were collected at random from the population; 18 of these (55%) contained ova of *S. haematobium*.

In the Vittorio d'Africa region, about 40 km (25 miles) from Genale, a muddy rain-water pool containing *Panicum* and in which people were spearing fish was examined for snails, with negative results. At Audegle, *Lanistes*, *Bulinus (Pyrgophysa) forskalii*, and *Syncera* were found in the remnants of a rain-water pool.

At Margherita, the River Juba was examined for snails with negative results; the basins of a mosque were also negative, while marshy water collections contained *Cleopatra*. Further upstream, neither the River Juba nor various other water collections near it and along the road yielded any molluscs.

At Gelib, 30 urine samples from the local school showed 6 positive for *S. haematobium* (20%).

At Urufle, 20 urine samples and 8 stools were collected from the villagers; of these, 11 (55%) urine samples were positive for *S. haematobium*, while the stools were negative for bilharziasis.

The River Juba at Urufle is about 80 m (260 feet) wide, has steep banks standing about 6 m (20 feet) above the water, and contains little vegetation. *Syncera* were picked from the bottom of a boat. Very large *Pila (Ampullaria)* were collected in fields which had previously been flooded by the river.

Results of the urine and stool examinations are summarized in Table XII and a list of the molluscs collected is given in Table XIII.

Discussion

It appears that in the north-eastern section of the Somali region, comprising south-eastern Ethiopia, the French and British Somalilands, and northern Somalia, bilharziasis is either absent or very rare. A strong endemicity for bilharziasis haematobia exists, however, in southern Somalia, mainly in, or along the margins of, the two river valleys of the Webi Shebeli and the Juba. Endemicity for *S. haematobium* has also been reported by Blair [16] from the adjoining coastlands of Kenya in the south.

In Somalia, irrigation bilharziasis has been gradually gaining importance and the local authorities are now fully aware that organized action is advisable. The real extent of the disease, however, needs assessment, as most of the former reports were based on clinical diagnoses, while more recent microscopic examinations have been conducted mainly among patients attending at hospitals and dispensaries and complaining of haematuria or showing other clinical manifestations. As pointed out by Lipparoni,[58] the first stages of the disease—which is as yet relatively benign and taken lightly by the population—practically always escape clinical observation; systematic microscopic examination would reveal a greater number of cases. The author's summary checks, made in widely separated endemic zones, gave an overall incidence of 41% among the population of the river valleys (see Table XII).

From Lipparoni's population survey in the Villaggio region and from the hospital records (Table X), it would seem that the disease in Somalia is more prevalent in adults; this tends to coincide with the author's own check surveys, in which infection-rates in adults were 55% and in schoolchildren 20%-35% (see Table XII). It is possible that pupils might belong to population groups more highly evolved socially and less exposed to infection, or that the children in general have not yet reached the age at which religious ablutions are considered obligatory. It should be noted, however, that existing data are not sufficiently representative.

The evident vector—that is, the only pertinent species present in the rivers, irrigation streams, and rain-water collections—is *Bulinus (Physopsis)*. Judging by shell characteristics, the species seems of a type intermediate between the two subgenera of *Bulinus*. Snail habitats in irrigation areas closely resemble those found in Egypt.

More data are required both on snail distribution and human incidence of the disease in Somalia.

Great interest in bilharziasis was shown by doctors and health officials, who were experimenting with new methods of treatment, for example trials with Nilodin, and who were eager to obtain samples of the fruit of *Balanites aegyptiaca*, recommended by Archibald [8] for its molluscocidal action.

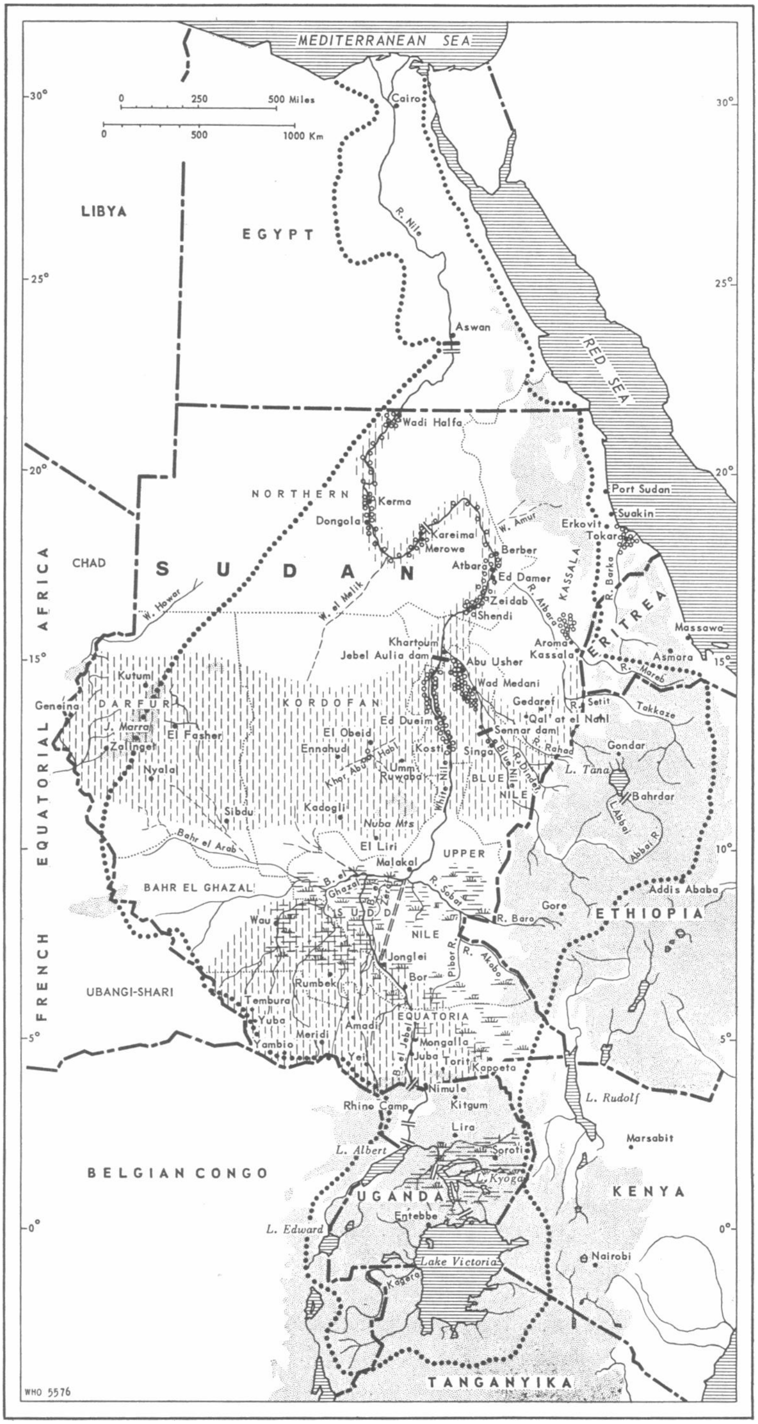
THE SUDAN

General Description

Geographical

The immense territory of the Sudan (see Fig. 5) covers about 2 700 000 km² (1 042 000 square miles) (roughly one-third of Europe or almost one-tenth of Africa) and lies between latitudes 22°N and 3°N. Broadly speaking, it is one vast plain, situated at an altitude of about 400 m (1300 feet), bordered to the east by the high Ethiopian plateau, and to the south by the highlands of the East African countries and the Belgian

FIG. 5. THE SUDAN



Congo, while to the west and north it merges into the plains of French Equatorial Africa and the deserts of Libya and Egypt. The plains are broken only by the volcanic Marra range of western Darfur and by the Nuba mountains of southern Kordofan, buried remains of a former topography emerging from the plains with a characteristic steep-sided beehive outline. The boundaries include part of the Ethiopian foot-hills and southern highlands.

The Sudan territory does not quite coincide with the Nile basin; it includes, in the north-east, a narrow zone draining from an elevated tract towards the Red Sea, and in the west, the Nile-Chad watershed, while the source regions of the White Nile, the Blue Nile, and the other eastern tributaries lie outside its boundaries. Also excluded is the northern part of the Nile basin.

Uniform conditions cannot be expected in such a large area, and noticeable geological, climatic, and ethnographical divergences exist within its boundaries.

Climate and vegetation zones

The Sudan has a typically tropical continental climate : it is pronouncedly dry and stable in winter and has intense rain-storms in summer, except for the extreme north, which has a characteristic rainless desert climate, and for a narrow Red Sea coastal strip, where maritime influences produce winter rains. The rains gradually increase in amount and in duration from north to south, the mean annual rainfall progressing from zero to 1500 mm (60 inches) (see Fig. 6). The peak of the rainy season occurs during July and August, except in the extreme south where the equatorial double rainfall maxima can just be detected.

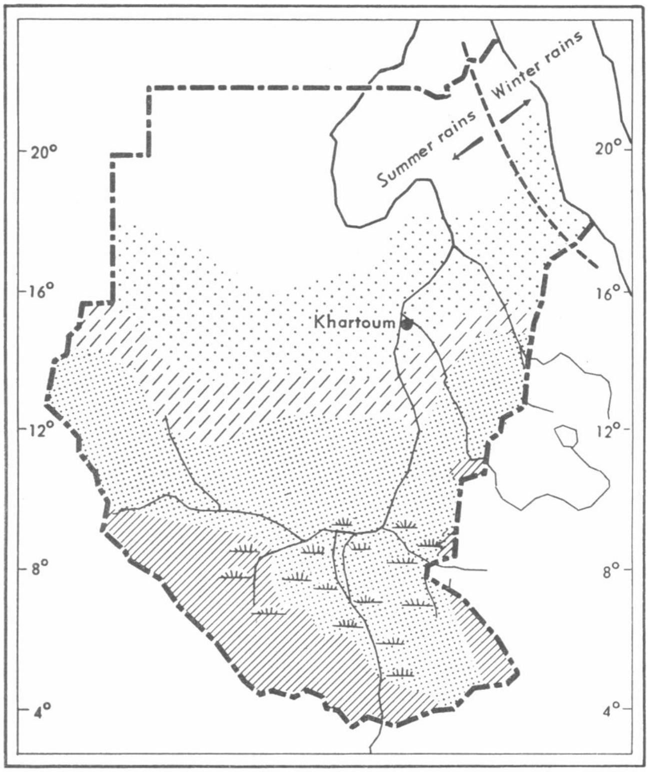
The mean seasonal variation of temperature in the Sudan, expressed in mean monthly maxima and minima, is 40°-8°C in the north and 33°-19°C in the south. The highest temperatures in the north occur during June and July; further south they occur progressively earlier, preceding the rains. The lowest temperatures, throughout the country, occur in winter, usually in January.

Legend to Fig. 5 :

- Above 1000 m (3300 feet)
- Irrigated
- Swamps
- Dams
- Projected dams and Sudd channels
- Endemic bilharziasis
- .... Boundary of Nile Valley basin

The provincial boundaries are indicated as at 1951; changes have since been made.

FIG. 6. RAINFALL AND CLIMATIC ZONES OF THE SUDAN



Mean annual rainfall (mm)	Zones of vegetation	Percentage of total area	Agriculture
0 – 50	desert, arid	24	dependent entirely on irrigation
50 - 300	semi-arid, scrub, acacia	24	
300 – 500	short grass scrub, acacia	10	both irrigation, and short crops under rainfall
500–1000	tall grass forest, acacia	25	rainfall cultivation
1 000 and above	savanna, broad-leaf forest	12	
	swamps, rivers	5	

tropical continental climate \ coastal maritime climate

WHO 5577

After Ireland [49]

The vegetation belts closely follow the climatic zones (Fig. 6). Proceeding southwards, the tropical desert merges into steppe and increasingly lush grasslands, interspersed with acacia trees. Open forest accompanies river valleys. In the extreme south-west, closed tropical forest is interspersed among the tributaries of Bahr el Ghazal.

Water-supply and agriculture

Of the total annual volume of the River Nile, 84% comes from Ethiopia and 16% from the great central African lake plateau; during the dry season in winter, however, the bulk of the water comes from the great lake region through the White Nile (83%). Apart from the White and Blue Niles and the River Sobat, only a few rivers and lakes in the extreme south are permanent, most tributaries of the Nile system becoming disconnected pools or drying up entirely in winter. In the regions with less than 800 mm (32 inches) of rainfall (northern and western Sudan), most streams never reach the Nile.

From the geomorphology of the various regions through which it passes and the varying slopes of its bed, the present Nile is thought to be a comparatively recent amalgamation of several drainage systems, dating back to the pleistocene. The part of the Nile valley with the lowest gradient (about 1 : 100 000) occurs between Juba and Khartoum, the gradient being about 85 times steeper in the great lake region and about 15 times steeper in the cataract region north of Khartoum. The flat portion, today a wide plain deeply covered with alluvial soil and, in its southern part, with extensive papyrus swamps (Sudd region), was once occupied by an immense inland lake (Lake Sudd theory), into which the Albert Nile and the Blue Nile drained in separate channels. The connexion of this lake with the Proto-Nile and River Atbara, which already flowed in well-established channels, and thus the formation of the present White Nile, is supposed to have occurred some 20 000 years ago.

The tributaries from Ethiopia, which contribute 90% of the flood-water, have a steep gradient and are actively erosive in flood, bringing down a heavy load of silt : 100 million tons of sediment are carried annually past Wadi Halfa. The Blue Nile shows great seasonal variation; when in spate, it may discharge 300-400 times as much as at low water. The River Atbara is even more erratic during flood. At the height of the Blue Nile flood (August), the White Nile is ponded back above its junction at Khartoum. The White Nile is a much steadier river, its discharge during spates rising to only five to six times that of low water; its water, filtered in the Sudd region, is clear.

Underground water, primarily depending on rainfall, is also controlled by the type of deposit forming the surface. Thus, in the large central clay plain, extending over the Bahr el Ghazal and White Nile basins as far as

Khartoum, and crossing over the Blue Nile and the Atbara as far as Kassala, the clay forms a seal when wet, and little or no water sinks beyond the reach of the plant roots, even in areas of relatively higher rainfall (over 500 mm —20 inches). Infiltration is, however, good in the Kordofan sands, known as " qoz ", a belt of fixed Aeolian sands extending from Kosti, on the White Nile, westwards through northern Kordofan and central Darfur to French Equatorial Africa; infiltration is also good in the Nubian series of interbedded sandstones and mudstones occurring mostly in the northern regions of the Sudan and in the lavas of the western Jebel Marra and Jebel Maidob as well as in the eastern volcanic Gedaref.

In many parts of the Sudan, small reservoirs (" hafir ") are excavated, or natural depressions (" fula ") are deepened to increase their capacity; both preserve rain-water until late in the dry season. From pits dug in the beds of these reservoirs at the end of the dry season, an additional water-supply is obtained which often lasts until the following rains.

A large programme of water-supply improvement is under execution to reduce pressure on riverain areas. Wells and deep bores are sunk at the rate of approximately 7000 feet (2100 m) per annum, while the annual excavation capacity for surface-water reservoirs amounts to 800 000 m^3 (176 million gallons). Use is being increasingly made of subsoil water for irrigation purposes by private enterprise and agricultural development companies alike.

In a large part of the country—namely south of the 500-mm (20-inch) isohyet—agriculture is almost entirely dependent upon rainfall. The system prevailing in the grassland belt of medium rainfall is called " harig " (Arabic for " burning "); after the early rains have germinated the weed seeds, advantage is taken of a dry spell to burn off all the grass, leaving the land refertilized and free from weeds. After one or more crops, the land is allowed to revert to grass. Throughout the southern Sudan forest areas, primitive native agriculture, with its shifting cultivation, is general. North of these regions, where rainfall is deficient, agriculture depends partly or wholly on irrigation. The irrigated tracts amount to about 0.5% of the total area of the Sudan.

Two torrential intermittent rivers, the Gash (Mareb) and the Baraka, descend from the Eritrean plateau into the eastern Sudan, reaching the plains in June-July and remaining in flow for about three months. On their extensive flood-plains, or deltas, cotton and food crops are grown, mainly by sheet (basin) irrigation.

The inland Gash delta, near Kassala town, covers roughly 700 000 acres (285 000 ha). About half this area is now served by over 500 km (310 miles) of canals under a measure of water control, but actually only about one-tenth to one-fifth is cultivated annually. The flow is very variable; the average flood volume is about 500 million m^3 (110 000 million gallons) or some 0.7% of that of the Nile. Rain-farming is also practised.

The Tokar delta, on the Red Sea, covers roughly 400 000 acres (162 000 ha). Very little attempt has been made to train the extremely violent, short, and intermittent flushes of the Baraka. The rate of discharge at the height of a spate may be enormous (1200 m^3—264 000 gallons—per second or one-tenth of the record Nile flood of 1946). The areas watered vary from 30 000 to 135 000 acres (12 000-55 000 ha).

Another small scheme has recently been started from the Khor Abu Habl in Kordofan.

In the northern section of that part of the Nile valley which is situated within the Sudan, one large and several small depressions, in the Shendi and the Merowe and Dongola districts, are cultivated under the ancient system of basin irrigation, allowing one crop a year; the large basin at Kerma is annually flooded and drained by 245 km (150 miles) of channels. The average annual area under this system of irrigation is under 80 000 acres (32 000 ha), but may vary from 10 000-100 000 acres (4000-40 000 ha), according to the floods.

It has been estimated that another 30 000 acres (12 000 ha) along the river in this area are watered by a primitive lift system, either by " shaduf " (counter-balanced dipper), during the flood when the lift required is small, or by " saqia " (water-wheel), which has a higher range of lift.

Pump irrigation, begun on a small scale before the First World War, has enormously increased, especially under the impetus of the Second World War both in this area, and also further south, in the White Nile Reservoir upstream of the Jebel Aulia dam, as well as upstream of the Sennar dam on the Blue Nile. About 320 000 acres (130 000 ha) are at present irrigated by pumps in about 600 separate private and governmental schemes, and further extension is continually taking place.

The Sennar dam on the Blue Nile, completed in 1925 and situated about 360 km (225 miles) upstream from Khartoum (storage capacity 600 million m^3—132 000 million gallons) feeds the Gezira irrigated area, the largest and most important irrigation scheme of the Sudan and its only free-flow scheme. (The Gezira area is fully discussed in a later section (see pages 68-76).)

The Jebel Aulia dam, situated on the White Nile, some 40 km (25 miles) upstream from its junction with the Blue Nile at Khartoum, was completed in 1937 to provide Egypt with extra summer water; its capacity is 3.5 milliard m^3 (770 000 million gallons). Its effect on the river can be felt 600 km (370 miles) upstream and has caused a large riverain tract to be inundated, depriving some 70 000 semi-nomad families of the crops formerly grown on the moist land exposed by the falling of the river. Under the " alternative livelihood scheme ", fresh centres have been provided for these people, chiefly in the Abd-el-Magid area of the Gezira.

A chain of regulation works is planned in the upper Nile basin, with the double aim of storing untimely water for release when desired and of increasing the annual average discharge (assumed " standard year "= 70 milliard m^3 (15 400 milliard gallons)).

In Uganda, a dam is now being completed at Owen Falls, 2.5 km (1.5 miles) below the exit of the Victoria Nile from Lake Victoria. This dam will not only generate hydro-electric power for the industries of Uganda but will also make the lake the largest over-year storage reservoir in the world, storing about 100 milliard m^3 (22 000 milliard gallons) of usable water. With the main storage at Lake Victoria, a subsidiary regulator below Lake Kyoga is projected to keep that lake always full and thus avoid delays in the passage of water.

To assist regulation, plans have also been made to turn Lake Albert into a balancing reservoir of smaller capacity. The final position of the dam on the Albert Nile is still under discussion, but the choice is expected to fall either on Nimule, just across the Sudan border, or on Mutir, at a third of the distance from the lake exit to Nimule.

An important source of increase in the standard year will consist in reducing the losses of water now occurring in the Sudd region, where swamps absorb and evaporate about half the water of Bahr el Jebel (Albert Nile)—that is, from 9 milliard to 35 milliard m^3 (1980-7700 milliard gallons), averaging 15 milliard m^3 (3300 milliard gallons). The projected Jonglei Diversion Scheme will cut 35% of these annual losses by one or more canals short-circuiting the swamps and taking from Jonglei, on the Bahr el Jebel, to connect with the White Nile either at, or west of, the mouth of the Sobat river.

As regards the upper Blue Nile, in Ethiopia, a dam envisaging the storage of 26 milliard m^3 (5720 milliard gallons), is projected near the outlet of the river from Lake Tana.

On the main Nile, a dam was projected near Merowe, at the 4th cataract, for storage as well as flood protection, but will probably be dispensed with when the High Aswan Dam, planned 7 km (4.5 miles) south of the present dam, is erected. It is envisaged that this dam will be 182 m (about 600 feet) high, will have a 130 milliard m^3 (about 28 600 milliard gallon) capacity, and will serve for both annual and over-year storage. The reservoir will flood large tracts of land and will reach 600 km (370 miles) upstream, to Dongola, profoundly affecting the character of the Northern Province of the Sudan. In general, these regulation works will be followed by very marked repercussions, as the flooding of land will cause extensive migration, the new shores will usually be shallower and therefore more suitable for snail life, and the greatly increased irrigated areas will cause increased bilharziasis.

Population and economy

With 8 million inhabitants, the Sudan is very sparsely peopled. The population, partly settled, partly nomadic, is predominantly one of cultivators and graziers. In the northern Sudan, the indigenous negro and

Hamitic mixture has been further mixed with Arab blood and is now Arabic-speaking and Moslem. Seasonal as well as permanent immigration, mainly from the west, has been taking place steadily over a period of years, especially since the establishment of various development schemes. The isolated south is inhabited by a variety of negroid, Sudanese, and Nilotic tribes, speaking a multitude of languages.

The economy of the Sudan is based on agricultural and pastoral pursuits. Its satisfactory financial position is largely due to the revenues from the cotton crops, grown mainly in the large agricultural-development schemes already referred to: the Gezira Board (formerly the Sudan Plantations Syndicate), the Gash Board, the Tokar Board, and the " alternative livelihood scheme ". These are noteworthy for the share-farming system employed, whereby the tenants are allotted 40%-50% of the income.

The food requirements of the population are supplied from the country's own resources, with the principal exception of sugar.

Geographical Distribution of Bilharziasis

The information contained in the following paragraphs is compiled from the literature and supplemented by personal investigation.

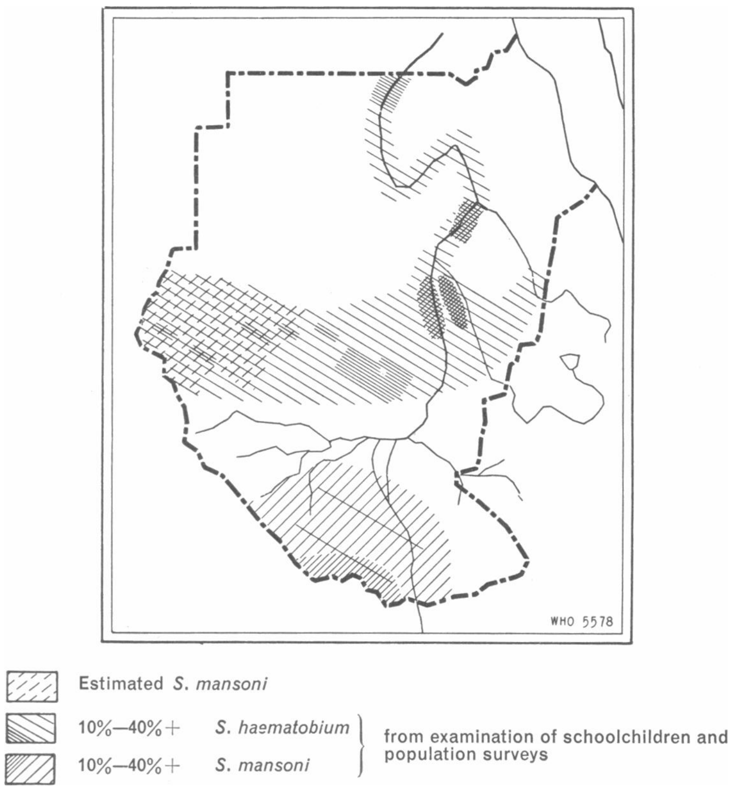
Bilharziasis of both types is endemic in various regions of the Sudan (see Fig. 5 and 7). The problem has attracted attention for over 25 years and a wealth of information is found in the annual reports of the Sudan Medical Service for this period,[91,92] as well as in separate publications by various officials. It appears that the disease does not yet correspond in full measure to the distribution of the vector snails, but is on the increase through human agency: it is introduced into new areas from endemic areas by movements of population and intensified by concentrations of human population, mostly in agricultural development schemes, which also provide new and favourable snail habitats.

Historical and general (see Fig. 8)

Vesical bilharziasis, if not endemic in the Sudan since prehistory, might well have been introduced from the ancient northern focus at various later periods. Pharaonic forts, temples, and inscriptions bear witness to repeated conquest and colonization in antiquity. In the 14th century, the Sudan was overrun by a wave of Arab conquest from the north.

According to Archibald,[7] Director of the Wellcome Tropical Research Laboratories, Khartoum, in 1933, there can be no doubt as to the flaring-up of bilharziasis in the wake of the Egyptian armies which, during the Ottoman conquest in the 1820's, reached Sennar on the Blue Nile and El Obeid in Kordofan, or which, after the reconquest of the Sudan in 1898, were stationed in several other districts; later surveys showed heaviest incidence in places previously occupied by troops or by Egyptian settlers and labour.

FIG. 7. BILHARZIASIS IN THE SUDAN : INCIDENCE

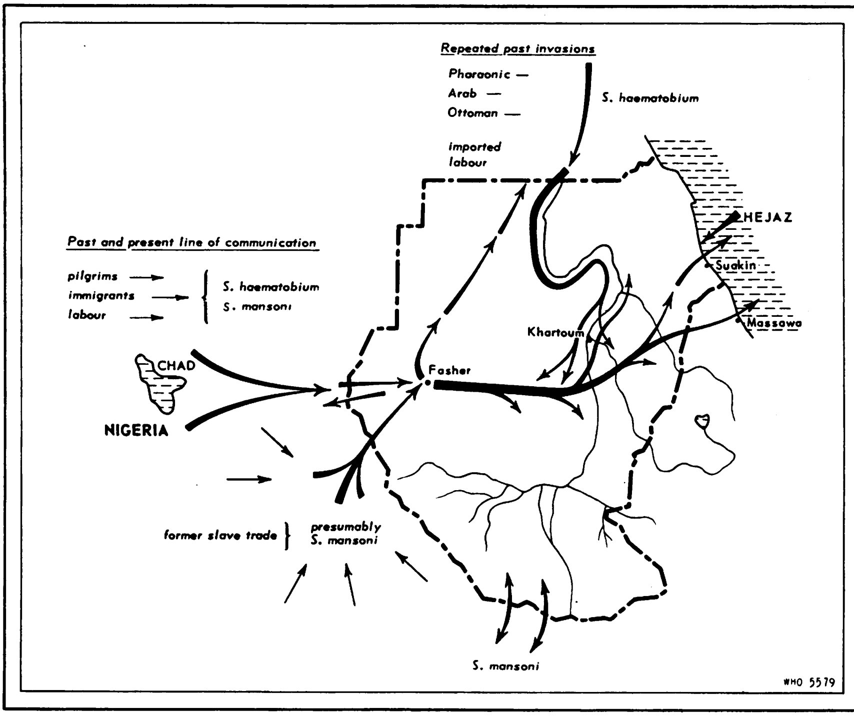


Throughout recent years, from 1000-2000 labourers have been entering the Sudan yearly at Wadi Halfa.

Another important and constant source of contamination for central Sudan, with regard to both types of bilharziasis, is large-scale traffic (transit and immigration) from the western territories—mainly from British West Africa and French Equatorial Africa—where, according to Gaud,[35] infections with both *S. haematobium* and *S. mansoni* range from medium to heavy, and also from Darfur Province which is homogeneous with adjacent Chad. Darfur has maintained constant communications with infected Chad and was also, in past ages, the starting point of slave caravans, where central Africans, presumably infected with *S. mansoni*, were assembled for the march northwards over the notorious Darb el Arba'in desert route.

There is a large yearly influx of labour, especially during the cotton-picking season, into the irrigated areas of the Sudan; in the Gezira area alone, this influx was estimated at 90 000 by Stephenson [90] in 1947. Of these labourers, about half are western Sudanese and West Africans, the former

FIG. 8. BILHARZIASIS IN THE SUDAN: PAST AND PRESENT DYNAMICS



(Humphreys [48]) being mostly young males earning the money needed for marriage, the latter usually pilgrims travelling to Mecca. Examination of these westerners at the protective bilharzia quarantine stations at Ed Dueim and Kosti, on the White Nile, between the years 1928 and 1933, showed an average *S. haematobium* infection-rate of 17.5%, the rates of incidence being about equal in the western Sudanese and the British and French West Africans. Examinations for *S. mansoni* were not made, as the infection was then thought to be uncommon, but Stephenson [90] has suggested that infection-rates are probably the same as those with *S. haematobium*.

A steady stream of pilgrims, from West Africa to the Hejaz and back, has been flowing through the Sudan for centuries and thousands have been passing through the Suakin quarantine station yearly for several decades. The records show clearly that the overwhelming majority of urinary bilharziasis cases discovered there occur among that group. These westerners belong mainly to the Hausa, Bornu, and Fulani races from Nigeria and the Borgu of French Equatorial Africa. Their main route of transit is via Chad to El Fasher and thence to the railhead at El Obeid. These as well as other Sudanese pilgrims usually travel in a most leisurely manner, stopping to work at various places for as long as one or two years, so as to earn their living. A number of variant routes are taken; formerly, large numbers of West Africans used to pass from the Sudan into Eritrea, to sail from Massawa and evade the quarantine duties at Suakin; among those returning via Suakin several persons are usually found who left Africa through Mombasa, Zanzibar, or Massawa. The epidemiological importance of these movements is evident.

TABLE XIV. ROUTINE URINE AND STOOL EXAMINATIONS IN THE SUDAN, 1949

Province (from north to south)	*S. haematobium*		*S. mansoni*	
	examined	positive (%)	examined	positive (%)
Northern				
Wadi Halfa *	24 556	8.1		
Merowe/Dongola *	44 239	6.5		
Atbara/Shendi			4 554	0.97
Khartoum	36 892	1.7	33 708	0.30
Kassala	15 803	3.2	11 354	0.45
Blue Nile				
Gezira *	81 027	8.9	81 027	8.8
White Nile Reservoir *	16 731	5.8	5 211	1.8
Fung	6 000	3.7	4 786	1.3
Kordofan	23 907	22.8	7 031	0.39
Darfur	11 306	17.8	2 307	0.2
Upper Nile	6 389	2.5	3 256	1.9
Bahr el Ghazal	3 481	0.25	8 503	4.9
Equatoria	357		1 403	44.3

* The figures for the districts thus marked were the results of random surveys. The cases from the remaining regions were, to a certain extent, selected samples; in many instances it is probable that some clinical indications turned the attention of the medical staff to examination of urine and stools. Males are stated to show a higher infection-rate than females, the highest rates occurring in boys of the age-group 5-15 years.

Table XIV shows the incidence of bilharziasis in the various provinces of the Sudan, as given in the annual report of the Sudan Medical Service for the year 1949; the data are based mainly on routine examinations of urine and stools in hospitals and dispensaries. This table does not provide an indication of autochthony in the areas of very low incidence, nor does it make evident the focal concentrations of bilharziasis in each of the large provincial territories. Moreover, the figures obtained by the above methods during 1949 show not inconsiderable discrepancies with those obtained in other years or from other sources. In general, it can be stated that these figures are not truly representative and that they are probably, in most cases, below the actual incidence, many of the lighter cases having escaped notice.

The sketch (Fig. 7, page 54) showing the approximate distribution and relative intensity of vesical and intestinal bilharziasis in the Sudan has been compiled, for the most part, from examinations of schoolchildren, as given in the annual reports of the Sudan Medical Service for the years 1939-49, and also from other, published and unpublished, sources (population surveys, dispensary records of previous years, etc.).

It can be seen from Fig. 7 that the arid northern and Red Sea deserts are considered to be free from endemic bilharziasis. A practically non-endemic zone, extending across the country between the latitudes 12°N and 8°N, separates a northern steppe-belt of mixed, but predominantly vesical, infection, from a southern zone of endemicity where intestinal bilharziasis prevails in the savanna and forest plateau, which is topographically and ethnographically homogeneous with the bordering regions of Uganda and the Belgian Congo. This non-endemic belt, where bilharziasis is rare even along the infiltration line of the Nile, is believed to be more or less free from the disease, because it lies outside the main transit routes (compare with Fig. 8, page 55), the high Ethiopian massif and the swamps forming an effective barrier to population movements.

The highest incidence of *S. mansoni* infection (in certain places from 60% to 90%) has been found for many years on the White Nile, south of Khartoum; *S. haematobium* also occurs. Both types of bilharziasis have already established themselves firmly in the Gezira irrigated area. In the Sudan, it is impossible to estimate the true infection-rates of *S. mansoni*; in general, detailed data for this form of the disease are few in the records, the term bilharziasis often being used without specification. This relative lack of information is due both to the technical difficulties of faecal examination and to the unwillingness of the population to furnish faecal samples. In Fig. 7, the incidence of *S. mansoni* in Darfur Province has been estimated from analogy with the adjacent Chad region.

It should be noted that throughout the Sudan vesical bilharziasis has been considered a relatively mild disease, from which cases usually recover in later life, while bilharziasis mansoni, at least as it occurs on the White Nile, has been recognized as progressively and gravely debilitating.

In the steppe areas of natural endemicity in the Sudan, acquisition of infection with bilharziasis is seasonal, not, as in Egypt or Iraq, on account of the lower winter temperature but, as pointed out by Archibald,[7] on account of the higher concentration of cercariae in the dry season when the water becomes shallow. The dangerous season in the inland stretches of water is from October until the end of January, and in the backwaters of the Blue and White Nile from February to June. This does not apply to the irrigated areas, where human infection occurs all the year round and where bilharziasis is correspondingly more severe.

Bovine bilharziasis, judging from the meat market at Khartoum and from cattle exported to Egypt, is believed to be fairly prevalent, but does not appear to occur in man in the Sudan.

Incidence and ecology of vector snails

Both *Bulinus* s.s. and *Biomphalaria*,[a] the two recognized snail vectors, as also *Bulinus (Physopsis)*, known to serve as a vector in other African regions to the west and south, are found in the Sudan.

According to Archibald [7] and to the early annual reports of the Sudan Medical Service, *Bulinus* s.s. occurs in both the Blue Nile and the White Nile, even when these rivers are in flood, as well as in the seasonal and temporary inland rain-water lakes, ponds, watercourses, and water reservoirs (" hafir ", " fula "). It had apparently not been obtained south of latitude 11°45′N, the latitude also given as coinciding with the southern limit of endemicity for *S. haematobium*. Nevertheless, the author had no difficulty in finding *Bulinus* snails proper in Malakal (latitude 9°38′N), in a weedy " khor " (" khor "= any depressed tract containing water, either temporarily or permanently) from the White Nile, and in two-year-old channels of the experimental Jonglei Agricultural Scheme south of Malakal.

Biomphalaria was reported by Archibald[7] from the inland lakes of the south, from the Blue Nile, and from the White Nile, the genus being especially common in the slower-flowing White Nile. No specific mention was made in his, or other, descriptions of *Biomphalaria* in the water collections of the west, which were cited as containing bilharzia snails. From general ecological considerations regarding western Darfur and the adjacent southern Chad, the author thinks it not unlikely that *Biomphalaria* may occur. Regarding the east, the author learnt that *Biomphalaria* had been found at Erkowit, in the Red Sea Province, where bilharziasis so far is not endemic. The snails were breeding in the stagnant waters behind soil-conservation dams and at the base of the stone-pitching at the face of the dams.

Today, both *Bulinus* s.s. and *Biomphalaria* occur in the various irrigation channels fed from the White, Blue, or main Nile.

As regards *Bulinus (Physopsis)*, Archibald [7] reported in 1933 that, in the Sudan, the subgenus had never been obtained from the Blue or the White Nile, but only from the rain-water lakes in the south. No naturally occurring bilharziasis infections were observed in these snails, which had been found in an area where *S. haematobium* is not endemic;

[a] See section entitled Malacological Notes (page 93).

attempts to infect them in the laboratory at Khartoum also failed. Later reports concerning *Bulinus (Physopsis)* do not appear to exist, except for one doubtful identification in the Gezira area, referred to by Greany,[40] which is discussed more fully in the section entitled Malacological Notes (see page 93).

It would seem that the central and western parts of southern Sudan, which are homogeneous with the woodland and higher rainfall zones of Uganda and the Belgian Congo, form the northern limit of incidence for the subgenus in this part of Africa. Pilsbry & Bequaert [76] reported that the subgenus is commonly found across the border in the Niam-Niam [a] country of the Belgian Congo; they stated that the Nile-Congo divide is not very pronounced and that the streamheads of Bahr el Ghazal and those of the southern drainage system often connect by swamps at the end of the rainy season, pointing out the zoogeographical importance of these facts. They also stated that *Bulinus (Physopsis)* does not occur in the large African lakes and rivers, but in the smaller lakes, in pools, swamps, and quietly flowing rivers.

At Juba, in southern Sudan, the author found *Bulinus (Physopsis)* in a " khor " connecting with the Bahr el Jebel or White Nile. This habitat was in conformity with the well-known predilection of the subgenus for quiet waters, but it can hardly be doubted that the snails in the " khor " reached it via the White Nile.

With regard to the upper reaches of the Blue Nile, the author found *Bulinus (Physopsis)* not only in Lake Tana, a large lake with little vegetation and a marked wave action, but also in the rapids of the Blue Nile below its exit from the lake—by no means a quiet habitat.

The resistance of the aquatic molluscan vectors to desiccation deserves a short discussion. It has been well known for a number of years that even those rain-water bodies of the Sudan which dry out completely for a great part of the year harbour a well-developed population of *Bulinus* s.s. and other species (Sudan Medical Service annual report for 1929). Barlow,[18] in 1933, pointed out that immediately after the beginning of the rains full-grown *Bulinus* s.s. were found in large numbers in lake beds which had been completely dry for six months (December-May), proving that they were therefore able to survive prolonged drought. According to Annecke & Peacock,[6] the same is true of the grass-pans of the Transvaal, where *Bulinus* s.s. and *Bulinus (Physopsis)* have been found to revive even after an exceptional drought lasting 18 months.

A list of the snail samples collected by the author in the Sudan is given, with brief comments, in Table XV. Further details on collection are found in later paragraphs of this section, while systematics are discussed in the section entitled Malacological Notes (see page 93).

[a] Nickname for the (once cannibal) Azande tribes

TABLE XV. FRESHWATER GASTROPOD MOLLUSCS COLLECTED IN THE SUDAN

Serial No.	Place of collection	Description	Species
	Equatoria Province		
43	Khor, taking from Bahr el Jebel (Albert or White Nile), near Juba	Very weedy; algae, *Panicum*, etc.	*Bulinus (Physopsis)* sp. * *Lymnaea natalensis* *Bulinus forskalii* *Gabbia senaariensis* Küster ** *Anisus* (*Gyraulus*) *natalensis* Krauss **
44	Khor, also taking from Bahr el Jebel, 4 km south of Juba	Very weedy; algae, *Panicum*, etc.	*Biomphalaria* sp. * *Bulinus forskalii* *Lymnaea natalensis* *, ** *Anisus* (*Gyraulus*) *natalensis* *Bulimus* (? *Gabbia*) sp. †
	Upper Nile Province		
40	" Jonglei agricultural scheme ", south of Malakal	stream 3 m (10 feet) wide, then 25 cm (10 inches) deep; *Panicum* and other weeds	*Biomphalaria* sp. * *Bulinus truncatus* * *Cleopatra bulimoides* *Bulinus forskalii* *Gabbia* (*Bithynia*) *senaariensis*
41	Khor from White Nile, 3 km south of Malakal	stagnant, 3-4 m (10-13 feet) deep in centre, very weedy	*Bulinus truncatus* *Cleopatra bulimoides* *Gabbia* (*Bithynia*) *senaariensis*
42	White Nile, at Malakal	boat anchorage; no weeds, low water	*Melanoides tuberculata* *Cleopatra bulimoides* *Gabbia* (*Bithynia*) *senaariensis*
	Blue Nile Province		
	(Abu Usher, Gezira)		
45	Gannab Canal	—	*Biomphalaria* sp. *Bulinus truncatus* *Cleopatra bulimoides*
46	Dolga Canal	5-6 m (16-20 feet) wide, *Potamogeton*, *Panicum*, *Polygonum*, etc.	*Biomphalaria* sp. * *Bulinus truncatus* * *Melanoides tuberculata* *Cleopatra bulimoides* *Bulinus forskalii* *Lymnaea natalensis*
	Kassala Province		
47	Hafir, at Wagar	dry	*Pila* (*Ampullaria*) *ovata*

*** See Fig. 10, and section entitled Malacological Notes, page 93.**

**** Identification by Mandahl-Barth (personal communication): note that *Anisus natalensis* Krauss, a species with many slowly growing whorls, does not occur in Egypt; as for *Gabbia senaariensis* Küster, the author is not able to distinguish it from the *Bithynia subbadiella* of Egypt.**

† Identification by Blair (personal communication); the species (sharply pointed apex) does not occur in Egypt.

NOTE:

(1) *Bulinus (Physopsis)* sp. (Serial No. 43); specimens of this series were identified as *B. nasutus* by Blair (personal communication) and as *Bulinus globosus* Morelet by Mandahl-Barth (personal communication).

(2) *Biomphalaria* sp.; all specimens would have unhesitatingly been called *B. boissyi* by the author. The samples of *Biomphalaria* sent to Dr Blair (Serial Nos. 40, 44 and 46) were termed " close to *boissyi* "; those sent to Dr Mandahl-Barth were identified as *B. sudanica* v. Martens (Serial No. 40) and as *B. rüppelli* (No. 46).

(3) *Lymnaea natalensis* Krauss, 1848, is considered synonymous with *L. cailliaudi* Bourguignat, 1883.

(4) *Other species;* the names currently used in Egypt have been applied to the other species collected, without attempting to obtain identification from other centres, the species being quite obviously the same.

Human incidence in the south

The extreme south. In order to follow up available data on the southern Sudan, it should be noted that the former south-eastern Province of Mongalla and the south-western Province of Bahr el Ghazal were combined in 1935 to form Equatoria Province, which was re-divided in 1948 in a different manner, the present Equatoria Province extending across the entire southernmost strip of the country and the present Bahr el Ghazal Province lying north of western Equatoria.

The first indication of the occurrence of *S. mansoni* in the old Bahr el Ghazal Province was given in 1934. In 1936, Cruikshank [25] reported *S. mansoni* infection to be common but mild in the south-west, amounting to 17% at Li Rangu dispensary, near Yambio. As late as 1940, and in a generally optimistic article, Atkey,[9] the Director of the Sudan Medical Service, stated that bilharziasis mansoni, although predominant west of the Nile, was benign and caused little incapacity among the inhabitants. In the annual reports from 1943 onwards, intestinal bilharziasis is listed, together with guinea-worm and ankylostomiasis, among the major health problems of the south. In 1945, the 2079 cases of bilharziasis recorded in the region were described as being caused practically entirely by *S. mansoni*, which implies the presence of some *S. haematobium*; in 1949, the first percentage of *S. haematobium* in the south is given as 0.25% of 3481 persons examined in Bahr el Ghazal.

The highest incidences of *S. mansoni* are found in a strip close to the south-western border (see Fig. 7, page 54) with the heaviest focus at Meridi, where examinations of schoolchildren in the years 1941-47 gave the results recorded in Table XVI.

TABLE XVI. EXAMINATION OF SCHOOLCHILDREN FOR BILHARZIASIS MANSONI AT MERIDI, THE SUDAN

Year	Number examined	Positive (%)
1941	90	53.3
1942	95	51.6
1943	70	45
1945	183	41
1947	168	38

The incidence of bilharziasis mansoni in schools at Li Rangu and Yambio varied from 10% to 22%, with 200-300 children examined each year. In Source Yubu district (Tembura), where about 300 children were examined yearly in 1941, 1942, and 1943, the incidences were 9%, 15%, and 28%, respectively. Incidence in Yei reached 21% of 89 pupils in a village school in 1943 and 22% of 96 pupils in a girls' elementary school in 1947, but fluctuated considerably in other schools and years.

In Wau district, now southern Bahr el Ghazal Province, the incidence of *S. mansoni* fluctuated between 3% and 13.5% from 1941 to 1947, about 1000 children being examined each year. Incidence in the lake district (Rumbek area of the present Bahr el Ghazal Province), in Juba (on the Nile), and in Torit (east of the Nile), was about 2%-3% during the same period. In all those years no cases were found in Kapoeta, east of Torit, and it was stated in the annual report for the year 1945 that efforts were being made to prevent the introduction of the disease there. The extreme south-east has few settlements and bilharziasis is not known to occur. Since, however, a case has been reported from the eastern plains, on the Ethiopian side of the frontier, it might be conceivable that cases could exist in the eastern territories of southern Sudan. The disease is also no problem in the unpopulated and tsetse-fly infested plateaux west of Tembura.

The high incidence of *S. mansoni* in Meridi, Yambio, and Tembura districts, which are inhabited by the Zande tribe, is probably not unconnected with the resettlement policy pursued in those areas, following the sleeping-sickness epidemic of 1918. For reasons of control and in order to facilitate the clearance of watering-places from tall undergrowth and thereby from the fly *Glossina palpalis*, the population was concentrated, between 1922 and 1924, in settlements along roads. In the new Zande development scheme, 200 000 people are to be resettled in model villages and agricultural schemes.

The economic plans for the south, which aim at rural betterment, are, in the main, a drive towards self-sufficiency, to offset the difficulties of transport. The cash crops are to be mainly cotton but also sugar-cane and coffee. The development of internal and self-contained industries will be furthered, such as sugar production and the erection of cotton ginning, spinning, and weaving mills. It is easy to foretell the effect of these developments on bilharziasis : the disease is bound to increase, despite the fact that the Government is planning to provide latrines and sanitary water-supplies.

An example of the rapid increase of bilharziasis incidence through concentration of population was given by Schwetz [87] in 1951, for a nearby district in the Belgian Congo : the Kasenyi plain on the western shore of Lake Albert. *S. mansoni* was first reported from that area in 1926. After the establishment of large-scale fisheries, the incidence rose to 33%-44% in 1938-39. In 1947, incidence among the fishermen employed by the companies and also among the population descending from the hills to fish, amounted to 70% and in certain places even to 90% and 100%. Native workers engaged solely in loading merchandise on a wharf and in no way connected with fishing, were found to be infected at the rate of 40%.

The distribution pattern of bilharziasis in southern Sudan parallels that met with in Uganda south of the Sudan border, at least as far as bilharziasis mansoni is concerned. According to Blair,[16] the latter form of the disease is prevalent in the grass and forest lands of north-western Uganda. In 1939, *S. mansoni* was said to have assumed serious proportions in the West Nile Province of Uganda and to be spreading to the east. The incidence in schoolchildren in that year was 12% ; in 1950, it was 54%. Bilharziasis haematobia is found in the drier north-eastern part of Uganda and seems to be slowly spreading west. As regards the arid northern district of Kenya, Blair [16] reports that *S. haematobium* is found in patches, especially near semi-permanent waterholes.

Although no data are available for the south-eastern Sudan, the author thinks it possible that the situation might be similar to that found in the adioining regions of Uganda and Kenya, with which the area is more or less homogeneous.

While at Juba, the provincial headquarters of Equatoria, and wishing to check up on the alarming increase of bilharziasis mansoni apparent in the Sudan Medical Service annual report for 1949, which amounted to an overall incidence of 44% from 1400 examinations, the author obtained the latest unpublished figures from the official records; these are given in Table XVII.

These figures correspond to those given in the annual reports for the years 1939-49, with high incidence at Yambio, Meridi, Tembura, and Yei. It is apparent, however, that the efforts made to keep the disease out of the Eastern District have not been successful.

TABLE XVII. STOOL EXAMINATIONS FOR S. MANSONI IN EQUATORIA PROVINCE, THE SUDAN, DURING 1951

District or area	Schoolchildren			Hospital patients		
	examined	positive		examined	positive	
		no.	%		no.	%
Central (Juba, Rejaf)	480	15	3.1	18 328	1 035	5.6
Amadi (Lui)				8 623	259	3.0
Yambio (Li Rangu)				820	308	37.6
Source Yubu (Tembura)	559	—	—	1 360	218	16.0
Yei		16	--	11 421	1 370	12.0
Meridi	147	45	30.6	2 052	506	24.7
Torit	1 164	29	2.5	7 732	358	4.6
Eastern (Kapoeta, etc.)	136	1	0.7	2 826	72	2.5
Total	2 486	106	4.3	53 162	4 126	7.8

In order to form an opinion on the discrepancy in the figures for 1951 and those for 1949 quoted above (4%-8% and 44%, respectively), the author examined various groups of people at Juba, which lies in a low incidence area.

All urine specimens examined (60 samples) were negative for *S. haematobium*. At the Juba school, the stools of 39 pupils aged from 7 to 16 years were examined and 20 out of 39 were found to be infected with *S. mansoni* (51%). These originated from Juba, Bor, Mongalla, Meridi, Amadi, and Torit. At Juba hospital, 10 male and 10 female patients were examined, 5 men (50%) and 3 women (33.3%) were infected with *S. mansoni*. These findings agree with those given for Equatoria Province in 1949 (44%).

The author believes that the evident increase in bilharziasis mansoni in the south is due in part to increased observation and knowledge, but also corresponds to an actual increase in incidence. The people are fond of bathing in the river ; while collecting snail samples at Juba, the author came upon a party of about 50 women, evidently using the river as their habitual bathing-place. The transmission of the disease, however, is not easy to explain. The people are said to deposit their stools away from the river; they are not Moslem and do not perform ablutions. It may be that the rains (May-September) play a part in carrying the infection to the water.

Several " khors " communicating with the Nile were examined for snails. *Bulinus (Physopsis)* and *Biomphalaria* were obtained (see Table XV). In certain places where malariol had recently been applied, no snails could be recovered.

Upper Nile Province. The zone between latitudes 12°N and 8°N, already referred to (page 57), has always been considered by the Sudanese authorities as being non-endemic for bilharziasis. In the annual report for 1945 it is stated for the first time that 53 cases of bilharziasis haematobia and 43 cases of bilharziasis mansoni had been recorded in Malakal, but it is expressly added that bilharziasis is not endemic in the Province and that it is desired to maintain its exclusion. The incidence of bilharziasis (unspecified) in schoolchildren at Malakal has been fluctuating between 0% and 4% during the years 1939-40. In 1949, the incidence is given as 2.5% *S. haematobium* and 1.9% *S. mansoni*, without further comment.

In order to form a personal opinion on endemicity, the author examined urine and stools from 62 schoolboys between the ages of 7 and 16 years, and followed up the origin of infections. Out of 61 urine samples, 2 were infected with *S. haematobium* (3%) while out of 55 stools, 2 showed infection with *S. mansoni* (4%). One of the boys infected with *S. haematobium* came from El Liri, a marshy place in the Nuba mountains, and had been in Malakal for five years. The other had come, two years previously, from Um Gar, a marshy locality on the White Nile, where a big cotton-farming project has been established and where bilharziasis is known to have occurred before. This same boy was also infected with *S. mansoni*. The second case of *S. mansoni* infection came from Khartoum.

These findings seem to corroborate the assertion that bilharziasis is not at present endemic in Equatoria Province ; however, since the occurrence of both *Bulinus* s.s. and *Biomphalaria* snails in the area has been demonstrated by the author, the establishment of both forms of the disease may be merely a question of time. Methods of agricultural development are already being studied in the new experimental Jonglei Agricultural Scheme. The author showed that the 2-year-old channels of the scheme, which were believed to be free from vector snails, were already forming an excellent snail habitat. In two dips the author collected 73 *Biomphalaria* and 8 *Bulinus (Bulinus)* sp. together with 3 *Bulinus (Pyrgophysa) forskalii*, 19 *Cleopatra*, and 7 *Bithynia (Gabbia)*. In the " khors ", *Bulinus* s.s. were also obtained, but many more dips resulted in fewer snails.

Human incidence in the Western steppe belt (Darfur and Kordofan Provinces)

Vogel,[97] in 1941, drew attention to the marked endemicity of vesical bilharziasis in the steppe and savanna belts of Africa, contrasting the focal incidence in those zones with the sheet-like spread of the disease in irrigated areas ; Gaud,[35] in 1951, also remarked on its pronounced spread in the zones bordering on the Sahara. The explanation given for this endemicity is the concentration of population around relatively few watering-places ; as these shrink with the oncoming of the dry season, the concentration of snails in a lessening volume of water adds to the opportunities for the successful completion of the life-cycle of the parasite. In better-watered areas beyond the savanna belt, these conditions do not prevail and bilharziasis is more diffuse.

The conditions described in the preceding paragraph have been interpreted, in the Sudan, from the viewpoint of comparison of natural endemicity with the heavy infections occurring in the irrigated areas. Thus, vesical bilharziasis in the western zones of natural endemicity has been described as mild and causing little inconvenience ; this is ascribed to the fact that infections are taking place only seasonally so that the degree of infection of the individual is relatively small.

In previous years, the overall incidence of bilharziasis haematobia in these districts has been estimated at about 17%, partly from observations at the bilharzia quarantine stations of Ed Dueim and Kosti, mentioned previously, and also from examination of settlers from the western districts in the Gezira area.

Darfur Province. Study of the incidence of vesical bilharziasis among schoolchildren in the various districts of Darfur Province may give a fairly good insight into the distribution of the disease. In the Sudan Medical

Service's annual report for 1929, 90% of the schoolboys of Sibdu, in the Baggara area of southern Darfur, were reported to be infected with *S. haematobium*, the infections taking place in large rain-water lakes. In El Fasher, 31% of 95 boys were also found to be infected. In later years, more representative examinations, covering over 1000 pupils yearly, were made in the Province. Study of the data from 1941-47 showed that the highest incidences constantly occurred in the Nyala and El Fasher districts, east of Jebel Marra, being on the average between 20% and 40%. Geneina district, west of Jebel Marra, showed incidences between 11% and 15% while incidences in different localities of the north and south of the Province varied from 0% to 9%.

In the annual report for 1943, it was stated that arrangements had been made to treat schoolchildren during school hours, in order that treatment should not be avoided. In 1945, it was noted for the first time that both haematobia and mansoni forms occurred, but in fact out of 1050 bilharziasis cases found in the dispensaries, only 2 were mansoni cases. In the report for 1949 (see Table XIV), routine examination of 11 306 urine samples and 2317 stools showed an incidence of 17.8% bilharziasis haematobia and of 0.2% bilharziasis mansoni. Although only few cases of bilharziasis mansoni have been directly reported, the author feels justified in assuming a feeble bilharziasis mansoni endemicity, analogous to that reported by Gaud [35] from the adjacent western zones of Ubangi-Shari and southern Chad. Nothing is known with regard to the presence of *Biomphalaria* snails in the area.

Kordofan Province. In Kordofan Province, where bilharziasis haematobia infection has long been known to exist, a total of several thousand schoolchildren were examined yearly during the same period. The highest incidences were found to occur steadily in the Nuba mountains of southern Kordofan, the percentages lying in the main between 35 and 47, although an occasional low percentage was found in one or another village. In central Kordofan—that is, the district around the capital, El Obeid—incidences appeared to have been rising: they fluctuated between 0% and 9% from 1941 to 1945 and were between 9% and 20% in 1947, only to fall again to 12% and below in 1948. In eastern Kordofan, the rate of incidence fluctuated between 0% and 18%. Incidences in northern Kordofan varied from 0% to 3%.

The annual report for 1945 stated, however, that bilharziasis was increasing in the Province, with 4253 reported cases against 3661 in the preceding year. In the annual report for 1949, a *S. mansoni* incidence of 0.4% is given for the first time (see Table XIV). As the place of origin of positives was not ascertained and as the region is not immediately adjacent to known endemic areas, the author does not believe the report to be sufficient indication of endemicity for *S. mansoni.*

Human incidence in the north and centre (Blue Nile and Northern Provinces)

Bilharziasis of one or both types is endemic, to a varying degree, along the lower courses of the Blue and While Niles and also along the course of the main Nile, the prevalence being related to the extent of irrigation in any particular area.

It has long been realized by the Sudan medical authorities that the spread of infection to new irrigation schemes would constitute a very serious health hazard. But until the fourth decade of this century, reports were optimistic; maintenance of infection at low levels or even prevention of the disease was believed to be possible by means of the various control measures applied. In later years, it was found that this had not been the case; thus, according to the annual report for 1947, bilharziasis continued to cause concern; while in 1948 it was reported that it must be accepted that the incidence of the disease was slowly increasing in irrigation areas and that the increasing number of pumps would bring in its train an increased incidence of the disease.

Northern Province (formerly Halfa, Dongola, and Berber). The course of the main Nile from Khartoum to Wadi Halfa lies in an arid zone, depending wholly on the river for its life. Bilharziasis haematobia is endemic throughout the zone and is described as benign; bilharziasis mansoni is confined to one area, the Zeidab Irrigation Scheme, south of Atbara, where the disease has been established since 1933. In 1934, a survey conducted among 167 persons showed a mansoni incidence of 56% (93 persons, from 3 villages).

Before 1918, bilharziasis haematobia was confined to a few villages in northern Dongola, but in that year Egyptian labour was introduced to canalize three pump irrigation schemes in the area and the inhabitants of these soon became very heavily infected with bilharziasis. Within a few years, the population of many of the villages up- and down-stream were contracting infection from " khors " and river pools. Since 1926, organized surveys and dispensary records, covering between 12 000 and 58 000 persons annually, have been made; these have revealed infections ranging from 2% to 18%, the higher infections being reported in 1928-29, while later years showed infections under 10%. Annual examinations of 2000-5000 schoolchildren revealed incidences ranging from 2% to 19% in various schools and years.

Similarly, in the Halfa area on the Egyptian border, annual examinations of 12 000-22 000 people, from 1934 to 1942, revealed from 2000 to 4000 cases a year, corresponding to incidences from 11% to 22%. Later records, comprising 4000-10 000 persons annually, showed similar infection-rates. Examinations in schools of the area, covering 1500-3000 pupils annually, showed infection-rates ranging from 2% to 84% in various schools and years, usually averaging from 10% to 30% in the boys' schools, and being lower in the girls' schools. The incidence, as related to the total population of the Halfa area, was given as 6% in 1941.

In annual examinations covering 2000-8000 schoolchildren, the incidence, in the Atbara-Berber region, ranged from 1% to 18% in various schools and years. Further south, in the Shendi area, the incidence ranged between 0% and 1.5%.

White Nile area of Blue Nile Province.[a] Bilharziasis haematobia has been recorded from the southern villages, where it is said to be acquired from rain-water lakes. Bilharziasis mansoni is endemic in the riverain villages from Jebelein to Jebel Aulia. In the Sudan Medical Service's annual report for 1929, the incidence was described as heavy and the constitutional effects were quoted as being very severe, giving rise to dysenteric symptoms with anaemia and marked debility. *Biomphalaria boissyi* is reported as very common in the shallow waters at the edge of the river and in the " khors " and pools; in October and November, no mature *Biomphalaria* or *Bulinus* are found, and only immature snails occur on the masses of reeds (" um suf "), which are carried down by the flood from the upper regions of the river; in March, mature snails are found in large numbers and maximum infectivity is stated to occur, when the water is low, from March until the beginning of the flood in early June. The extension of irrigation in this area within the past 20 years is reported to have aggravated the situation.

Southern Blue Nile area of Blue Nile Province.[b] Bilharziasis haematobia is endemic in the Blue Nile area upstream of Sennar, particularly in the pump schemes. Although the incidences in schoolchildren recorded over the years are low, immigration from Fung into the Gezira irrigated area was considered to be a potential danger in the Sudan Medical Service's annual report for 1930. In 1934, *S. mansoni* was reported from southern Fung—that is, the stretch of land, east of the While Nile, bordering on Ethiopia—with the remark that the distribution of this type of bilharziasis was probably more extensive than had been believed in the past.

The Gezira irrigated area. (1) General description. The Gezira is a flat bare plain, lying in the angle formed by the Whi e and Blue Niles before their confluence and covering 5 million acres (2 025 000 ha). Before the building of the Sennar dam in 1924, the area was an arid tract served by wells, and bilharziasis was practically unknown except for a few sporadic cases of haematobia infection close to the Blue Nile. Today, the irrigated area, which lies along the western bank of the Blue Nile, covers about one million acres (405 000 ha) and its long-staple cotton, the most important crop grown, forms the main source of revenue of the Sudan; further extension of irrigation is possible.

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[a] Formerly White Nile Province

[b] Formerly Fung

The prosperity brought by the scheme has resulted in an increase in population from an estimated 16 000 to 350 000, distributed in 980 villages and towns. The immigrant settlers have come from Nigeria, French Sudan, western Sudan, Northern Province and, since the building of the Jebel Aulia dam in 1934, also from the flooded While Nile area, all regions highly endemic for one or both types of bilharziasis. During the cotton-picking season, from January to March, there is also a considerable yearly influx of labour from these same areas, fluctuating between 40 000 and 90 000 persons, whole families arriving and camping out in the fields. At the present time, both bilharziasis haematobia and bilharziasis mansoni have become widespread and firmly established in the Gezira.

The scheme is served by high-level canals totalling a length of 4250 km (2650 miles), under a system of irrigation somewhat different from that practised in Egypt. The main canal, which measures some 200 km (125 miles), feeds about 20 major canals, measuring 750 km (470 miles); these ramify into numerous minor canals, totalling about 3300 km (2050 miles), which feed the field channels and often terminate in blind ends. Each of these branch systems is a separate entity that does not communicate with any other. Drainage channels in the proper sense of the word—that is, for draining the soil—do not exist, but there are 950 km (600 miles) of overflow drains and escapes carrying surplus surface-water back to the river.

Water enters into the main canal from the middle of July and flows until May of the following year. In order to furnish water to villages without wells during the ensuing summer closure, about two-fifths of the minor canals are maintained on summer water-supply; they are filled to the highest level and the supply is maintained by a pump which delivers water from the Blue Nile into the main canal at the southern end of the scheme, some 80 km (50 miles) below the dam. Consequently, water is practically stagnant in these minor canals, as well as in the major canals and the main canal, during the three months of closure.

All watering of crops is done by day, and this entails night storage in the minor distributaries, which are shallow, wide, and full of weeds. Only some 37 000 acres (15 000 ha) in the Abdel Magid area, in the north-west of the Gezira, form an exception in having a constant 24-hour flow of water, as in Egypt.

(2) Historical review. From the inception of the scheme, the inherent danger of the establishment of bilharziasis in the Gezira was realized. It was stated in the Sudan Medical Service's annual report for 1925 that if this were to occur, the result would be disastrous and probably irretrievable. It was realized that conditions were eminently suitable and that the infection might ultimately not only approach the situation prevailing in the Egyptian delta, but even surpass it in severity, in view of the warmer water temperatures all the year round and the resultant possibility of perennial infection. The history of the taking-root of the disease in the Gezira, within

the past 30 years, is a most instructive example to all authorities facing similar problems, now or in the future.

According to Humphreys,[48] who reviewed the situation in 1932, no vector snails were found one year after the beginning of canalization; in 1925, after 18 months, *Bulinus* s.s. were found in 6 canals; after two and a half years, in 1926, *Bulinus* s.s. were present in all canals and *Biomphalaria* in 9. In that year, 91% of 921 haematobia carriers were immigrants, but local contraction was already indicated by 37 infected children from widely scattered villages. A year later, both species of vector snails were established in all streams and in 1928 infected *Bulinus* s.s. were detected.

During the following decade, surveys covering from 11 000 to 50 000 persons of the indigenous population were made annually. At the same time, from 17 000 to 25 000 persons were annually examined in the 36 dispensaries then serving the area. Infected persons were treated. The *S. haematobium* incidences reported among the residents of the Gezira remained at approximately 1%, even in children. *S. mansoni* was not observed. The immigrants, especially the vagrant westerners, were, however, recognized as a grave danger.

Control of the disease was attempted by various measures. A quarantine station was established at Wadi Halfa for the screening and treatment of haematobia cases among Egyptian immigrant labour. As already indicated, similar quarantine stations were maintained from 1928 to 1933 at Ed Dueim and Kosti for immigrants from the west, which revealed an average incidence of about 17%, but which were subsequently closed because considerable evasion was practised. It should also be realized, in this connexion, that relapses are not infrequent among treated cases, that no screening was attempted for *S. mansoni*, which was believed to be negligible, and that at least two important sources for both types of bilharziasis from within the Sudan were not covered by the quarantine: Northern Province and the White Nile area north of Kosti.

A programme was carried out for re-siting villages, particularly those inhabited by westerners, at a minimum distance of 300 m (1000 feet) from the nearest canal (94 villages in 1934) and the building of new villages near streams was forbidden. Sections of various canals near villages were treated during the non-irrigation season, using Sizoline (a commercial carbolic) or Prince Regent disinfectant. Health propaganda by word and posters was applied. The entering of canals was prohibited but it was impossible to enforce this measure. A number of wells and deep pit latrines were installed in some villages; these, however, are inadequate in number even at the present time, and sanitation as well as water-supplies have remained primitive. The canals are still generally used for all purposes. So as to have water at hand for subsequent ablutions, it is still customary for the people to urinate and defecate on the edge of the canals, which are subject to night flooding so that the deposited excreta are washed into the irrigation system.

Although anxiety had been felt in the early years because it was thought impossible to eradicate bilharziasis from a large irrigation area once it had become established, and though the regular occurrence of a few locally contracted cases was disquieting, the continued low incidence of bilharziasis haematobia, recorded among the indigenous population of the Gezira, came to be considered as a sign of the success of the various precautionary measures taken to keep the disease under control. As late as 1939, the senior medical inspector for the Gezira expressed satisfaction that the increase in bilharziasis was slight and that the position had remained practically stationary.

It was not until 1942 that it was first indicated by Dr F. W. Wheaton, the medical officer stationed at Abu 'Usher, in northern Gezira, that the incidence of *S. haematobium* was higher than supposed and that *S. mansoni* was not infrequent. The data from the routine dispensary examinations continued to approximate to 1% but a special investigation, conducted from 1942-45 by Stephenson,[90] confirmed these suspicions. A survey for *S. haematobium* was made under his direction in 15 villages of the northern district, selected within the areas of the most reliable local medical assistants; from 70%-90% of their population was examined (2959 adults and 1814 children) and the average incidence was found to be 21% in adults and 45% in children (average 30%, range 1%-82%). Stephenson gave the minor canals as the main source of infection; he stated that of 293-376 infections recorded in the dispensaries of his area during the years 1942-44, from 59% to 81% had been locally contracted, and that the percentage of infection in immigrants did not exceed that for the indigenous population.

With regard to bilharziasis mansoni, the number of cases found in the dispensaries during the years 1941-44 varied yearly from 32 to 183, of which 40%-53% per annum were locally acquired, while the annual number of deaths due to bilharziasis mansoni varied from 4 to 7. No certain knowledge as to the actual overall infection could be obtained because of the difficulties involved in procuring faecal samples.

Stephenson found many more snails in the night-storage streams than in the continuous-flow systems at Abdel Magid, where the streams have more current, a steeper cross-section, and fewer weeds, and he advocated a change in the irrigation system. He also discussed in detail the failure of the prophylactic measures taken; he stated that the effect on the general health of the population had not become very noticeable so far, but pointed out that the rise in incidence, which had probably been gradual over a number of years, was likely to progress with increasing rapidity.

In 1946, Greany[40,41] began a comprehensive study of bilharziasis in the Gezira. He found *Bulinus* s.s. and *Biomphalaria* snails side by side and equally common in all canals, especially in the terminal portions. *Bulinus* s.s.

was a little more prevalent in the southern end of the canal system and *Biomphalaria* at its northern end. His snail counts did not differ in the night-storage and continuous-flow systems. He reported that in streams which do not dry out, snails are numerous throughout the year, except during the flood season (July to October) when the water is muddy; in the other streams, the snail population begins to multiply, together with the weeds, after the flood water has cleared, and the snails are numerous from December until canal closure in May. Snails from village watering-places were dissected for *Schistosoma* cercariae throughout all seasons. Infected *Biomphalaria* were found in every month, and the infection-rate in *Biomphalaria* was 20 times higher than in *Bulinus* (1.2% of 6001 *Biomphalaria* as compared with 0.06% of 5121 *Bulinus* s.s.).

He further reported that snail control, consisting of sulfations [a] in minor canals, was applied to a certain extent, and advocated applications in all canals at least twice yearly, in spring and in autumn, when the water is clearing. He also recommended that snail behaviour and ecology should be further studied with a view to biological control.

Human incidence was studied by a population survey covering some 81 000 inhabitants, or about a quarter of the population, living in 300 villages, widely and evenly distributed throughout the Gezira and so chosen as to be representative. Samples of urine and faeces were examined by concentration methods. *S. haematobium* and *S. mansoni* were found to be equally prevalent, although of uneven distribution; positives for *S. haematobium* amounted to some 7000, or nearly 9%, and about the same number of positives was found for *S. mansoni* (see Table XIV, page 56), the overlap being given as 3%. Infection-rates for both *S. haematobia* and *S. mansoni* were three times as high in children under 15 as in adults (15% and 5%, respectively). It was also found that the overall infection with both types of bilharziasis in males was about twice as high as in females.

Greany made an arbitrary differentiation between people having spent at least five years in the area, who were considered to be " local ", and those having settled later, who were termed " immigrant "; he found that infection with both forms of bilharziasis was more than twice as high in immigrant adults; among immigrant children, the infection with *S. haematobium* was also significantly higher, though it was about equally high with *S. mansoni*.

A study was made of the relation between bilharziasis incidence in children and the distance of the village from canals, the annual closure of the canals, the presence or absence of wells, and other factors. Analysis of the data relative to 186 villages, in which the number of children available for examination satisfied statistical requirements, showed that the only factor which lowered the incidence was distance, that is, if the village was

[a] Application of copper sulfate ($CuSO_4$)

situated more than 1 km (half a mile) from a canal, especially if wells were also present.

Greany [40] attributed certain irregularities in the geographical distribution of bilharziasis haematobia and mansoni in the Gezira to the patterns set by the first human disseminators of the infection, and correlated the comparatively late appearance of *S. mansoni* with the fact that immigrants from the White Nile area did not go to the Gezira until the flooding of their land in 1934. He also investigated the disease, in particular bilharziasis mansoni, with regard to its effect on the health of the affected population. He concluded that in the Gezira, bilharziasis haematobia, which has been common for the past 20 years, does not at present give rise to serious consequences, causing little else than discomfort and lack of efficiency, while mansoni infection, although it has not been established in the region long enough for its later stages to be reached with any frequency, is already causing debility, high morbidity, and even mortality. His observations on *S. mansoni* are based on various field studies and on a detailed clinical study of 410 patients whom he was treating from 1946-48. Observations on enlargement of the liver showed that *S. mansoni* was constantly associated with the condition. He also brought evidence that cirrhotic changes of the liver were primarily due not to malnutrition but to the presence of bilharziasis.

Having tried Miracil D (1-methyl, 4-diethylamino ethyl amino thioxanthone hydrochloride), at total dosages varying from 71 mg to 144 mg per kg of body-weight, as well as the intensive short courses with antimony salts, given intravenously and intramuscularly, advocated by Alves & Blair [3] and Halawani & Abdallah [44] respectively, Greany prefers the routine long courses of potassium antimony tartrate (PAT) for mass treatment campaigns. He treated about 9000 persons and reports that the treatment came to be regarded as beneficial by the villagers. At a maximum dose of 1.5 grains, no serious toxic symptoms occurred, while low relapse-rates were found in representative groups of patients (11%-14% after an average period of 5 months, 25% after 10 months).

In view of the increasing prevalence of bilharziasis, the health authorities asked Professors T. H. Davey and R. M. Gordon, of the Liverpool School of Tropical Medicine in 1951, to study and evaluate the situation with a view to subsequent control. Certain points made in their extensive report [27] are indicated in the paragraphs which follow.

They believe that the ultimate control of the disease can be achieved only when the indigenous population has adopted better standards of hygiene, and therefore stress the necessity for an intensive health education campaign, after the provision of safe wells and latrines. Since the improvement of hygienic standards can only be a slow process, they believe that the greatest hope of rapid improvement lies in the reduction of the snail population.

In view of the considerable expense of present-day snail-control measures, they recommend that these be preceded by research. They propose an extensive and detailed research programme, planned to cover a five-year period but subject to revision according to the preliminary results, and suggest the creation of a research team, headed by a medical doctor and including a freshwater biologist and several field assistants, with headquarters at the Research Farm at Wad Medani. They recommend that the head of the team should have a seat on the Gezira Board in order to promote co-operation with the irrigation and agricultural authorities and to broaden their outlook on health problems. In addition to undertaking research, the team would train Sudanese assistants, medical and zoological, in the techniques of investigation.

The programme recommended comprises various studies on epidemiology, snail bionomics, and snail control, some of which are mentioned in the following paragraphs :

Epidemiology

(i) study of the relative effect of bilharziasis and malaria, so as to determine financial priorities, by choosing three similar villages, the first to be treated for bilharziasis together with an intensive anti-snail campaign for two years, the second to be treated for malaria together with an intensive anti-mosquito campaign for the same period, and the third to be left as a control: the conditions in all three villages to be assessed by house-to-house surveys of the state of general health, with special reference to haemoglobin levels, days of absence from work, and mortality-rates

(ii) exact assessment of bilharziasis incidence by all methods, including post-mortem examinations, with special emphasis on tracing the origin and mode of infection

(iii) study of miracidial and cercarial densities and the manner in which their distribution is effected by the water-flow

Snail ecology and bionomics

(i) study of the distribution (active and passive) of snails in the canal system, and its relation to weed-growth

(ii) study of the effects of light, current, temperature, and chemical composition of the water on the growth and infectivity of snails

(iii) observations on the life-span of infected and non-infected snails

Molluscocides

(i) studies on copper sulfate with regard to its mode of action on snails, and determination of optimal concentrations, optimal spacing, and best method of application, with a view to reduction of cost without impairment of effectiveness

(ii) studies on new molluscocides

(iii) study of the effect of weed-killers on snails

(3) Survey. While at Khartoum, the author visited the Stack Medical Research Laboratories and obtained interesting data on the fate of copper after the sulfation of streams. It was found that the copper was precipitated as an insoluble complex with clay, which had no further lethal effect on snails, and evidence was obtained that weeds had absorbed an appreciable amount of copper. Mud scrapings were taken from the surface of the beds of two streams, both sulfated at 30 parts per million (p.p.m.) in April 1948; the mud from one canal, previously weeded, contained 960 p.p.m. after 2 months, while the mud from the other, weedy, canal, after only 15 days, contained 450 p.p.m., or less than half. In another experiment, two canals, only one of which had been weeded-out, were sulfated in October 1948 and simultaneously examined some 40 days later; the copper content of the mud from the weeded canal, sulfated at 30 p.p.m., was 350 p.p.m., while the mud of the canal retaining its vegetation, which had been sulfated at the double concentration of 60 p.p.m., had a copper content of only 250 p.p.m.

It was noted by the author that the standard of living in the Gezira is on the whole relatively high.

The design of the antibilharzial filter wells and storage tanks installed in various villages is of interest. These allow for the leading of canal water into a circular well, almost 2 m (6.5 feet) deep and 5 m (16.5 feet) across, where it is passed through two courses of bricks, graded gravel, and screened sand; a stop-valve connects the filter well with a series of three tanks, from which the water is taken in succession to facilitate its storage for 48 hours before use. It was learnt that an intensive human-treatment and snail-control campaign, to comprise one-fifth of the Gezira, has been undertaken in central Gezira.

Various dispensaries were visited. It was noted that the urine samples were sedimented for half an hour in large conical tubes, while direct faecal smears were examined, sedimentation being performed if these were negative. Liver and spleen examinations were conducted by the medical assistants as a routine measure.

An examination was made of the snail survey and sulfation procedures, which on the whole follow those used in Egypt. The author also noted the extensive, anastomosing road-net and, in particular, the constrictions of the canals at the regulators and at the numerous bridges and crossings, where the streams are siphoned under the roads. These narrowings provide excellent quiet snail breeding-places in the shoulders of the curves. The numerous blind ends, as well as the wide and shallow minor canals, appeared to afford equally suitable breeding habitats. The fact that the density of streams and villages is such that it is practically impossible for any village to be farther than 2 km (just over 1 mile) from a canal was also observed.

Snail checks were made in various places. Near Abu 'Usher, Dolga canal, a stream from 5 m to 6 m (16.5-20 feet) wide, with a very dense growth of *Potamogeton* and grasses, was examined; the snails recovered in one single dip were 40 *Biomphalaria* sp. and 25 *Bulinus truncatus*, together with some *Bulinus forskalii*, *Cleopatra*, *Lymnaea*, and *Melanoides*. Both vectors were also found, though in lesser quantity, in the other streams examined—namely, Gannab canal, near Abu 'Usher; the main canal, a few kilometres below the Sennar dam; and another canal near Abu Guta, in the Abdel Magid area. It was not considered necessary to preserve all samples, which were exactly alike. In the Sennar reservoir, a shallow and weedy stretch of water, only *Bulinus* s.s. was found, which corresponds with the findings of previous investigators.

At the Research Farm, Wad Medani, interesting observations have been made on snail- and weed-eating fish, and experiments have been carried out on the control of weeds by plant hormones and by the use of Fernoxone (a compound containing as active ingredient 80% of the sodium salt of 2,4-dichlorophenoxyacetic acid) and other related compounds.

Recent spread eastwards to Kassala Province

Before 1943, the reports of the Sudan Medical Service gave no indication of endemicity for bilharziasis in Kassala Province, the few cases found having been imported. In 1943, examinations in the schools of the Gedaref area revealed, for the first time, that 7% of 94 pupils at Qal' el Nahl elementary school were infected with *S. haematobium*. In 1944, dispensary records showed 151 positive cases from the area. In 1945, the number of positives had risen to 713 and it was stated that they had apparently contracted the disease locally from the " hafir " type of reservoir; 18 out of 26 " hafirs " were reported to contain *Bulinus* s.s. The incidence among the school-children of the area was given as 4% of 1518 pupils (61 cases); the number of cases from the neighbourhood of Kassala town itself was only 80. In 1946, bilharziasis was stated to constitute a problem of the first importance in preventive medicine. A total of 160 new cases was found, together with a number of fresh foci in several villages. It was stated that the disease had been introduced in recent years by the Fellata labourers, wandering from the western Sudan into the mechanical crop production scheme of the Gedaref area. Today, the disease is also associated with marshes and rain-water pools. In 1947, a further and more extensive survey revealed 504 bilharziasis cases from among 5356 persons examined; the incidence in a girls' school of the area was given as 11% of 107 pupils.

During his visit to Kassala Province, the author learnt that a number of *S. haematobium* cases had also been appearing in the dispensary records of the Gash delta. Case-histories were not available, but the occurrence of " bilharzia " snails in the " hafirs " of Wagar, in that area, was reported. Bilharziasis haematobia cases in Kassala town were, however, stated to be imported from other areas in the Sudan. The same evidently applies to all

TABLE XVIII. RECORDS OF BILHARZIASIS CASES FROM KASSALA HOSPITAL, THE SUDAN, 1949-51

Type of bilharziasis infection	Persons examined	Kassala region				Gedaref region			
		1949		1950-51*		1949		1950-51*	
		exam-ined	posi-tive	exam-ined	posi-tive	exam-ined	posi-tive	exam-ined	posi-tive
S. haematobium	men	2 621	60	1 650	113	2 253	217	10 682	430
	women	1 268	5	450	25	912	14	5 266	30
	children	1 327	27	2 100	227	790	2	4 884	249
	total	5 216	92	4 200	365	3 955	233	20 832	709
	percentage		1.8		8.7		5.9		3.4
S. mansoni	men	1 863	6	250	8	1 543	22	2 289	28
	women	645	2	125	4	845	2	1 626	0
	children	240	0	130	6	892	24	1 119	6
	total	2 748	8	505	18	3 280	48	5 034	34
	percentage		0.3		3.6		1.5		0.7

* 1950-51 = 18 months

mansoni cases recorded in the Province. Recent data obtained from the dispensary and hospital records are given in Tables XVIII and XIX. It was also learnt that, by 1950, bilharziasis haematobia had become endemic in 11 villages of the Gedaref area, situated mostly south of the railway track to Kassala in the stretch between the rivers Rahad and Atbara.

TABLE XIX. BILHARZIASIS HAEMATOBIA CASES FOUND IN THE GASH AREA, KASSALA PROVINCE, THE SUDAN, 1950-51

Village or town	Year	Persons examined	Positive for *S. haematobium*
Wagar	1950	36 789	60
	1951		22
Aroma	1950	26 697	11
	1951		1
Metateib	1951	24 432	1
	Total	87 918	95

The consultant examined the urine and faeces of 50 pupils, aged from 10-20 years, of the Kassala intermediate school, and found 6 boys infected with *S. haematobium*. Details of the infections are given in Table XX.

TABLE XX. DETAILS OF BILHARZIASIS HAEMATOBIA CASES FOUND AT KASSALA INTERMEDIATE SCHOOL, THE SUDAN, FEBRUARY 1952

Age of pupil (years)	Town/area of origin	Residence in Kassala	Remarks
12	El Obeid, Kordofan	6 months	
14	El Obeid area, Kordofan	4 years	
15	Gureir, Northern Province	10 years	
14	Qal'at el Nahl, Gedaref area	1 year	
12	Wagar, Gash area	1 year	
15	Kassala town	—	visited el Ordi, Dongola, for 2 months

It is seen that three boys had originally come from other known endemic areas, one had visited an endemic area, and only two had never left Kassala Province. The stools were all negative for *S. mansoni*.

At Kassala town, a " hafir "—two deep wells from which water is pumped into irrigation channels—and the channels themselves were

TABLE XXI. URINE AND STOOL EXAMINATIONS IN THE SUDAN

Locality	Persons examined		For *S. haematobium*		For *S. mansoni*	
	age (years)	sex	exam-ined	posi-tive	exam-ined	posi-tive
Equatoria Province						
Juba:						
public school	7-22	♂	40	0	40	20
hospital	13-38	♂	10	0	10	5
	19-45	♀	10	0	10	3
Upper Nile Province						
Malakal:						
3 schools	7-16	♂	61	2 *	55	2 *
Kassala Province						
Kassala:						
intermediate school	10-20	♂	50	6	48	0
Total			171	8	163	30

* imported

examined for snails, with negative results. It was noted that the northern " hafir " at Aroma was well protected by a fence, the only access to the water being from a wooden pier. This " hafir " and another at Metateib were also negative for snails. The " hafirs " at Wagar were dry at the time of the visit and the snail specimens, sent from that location at a later date, turned out to be *Pila (Ampullaria)*.

Examinations performed by the author

The results of the examinations of stools and urine for *Schistosoma* ova made by the author (already mentioned in the subsections on the various regions of the Sudan) are summarized in Table XXI.

Discussion

The main routine measures taken so far against bilharziasis in the Sudan are examination of the excreta of people presenting themselves at the various dispensaries and hospitals of the country, and treatment of those found infected. Schoolchildren are regularly examined and treated, as far as possible during school hours. It would be highly desirable to extend these measures to army recruits also.

In the opinion of Davey & Gordon,[27] bilharziasis outside the irrigated areas, although not uncommon, does not appear to affect the economic progress of the communities concerned, while even in the Gezira, evidence is lacking that the disease is, as yet, a threat to economic development, although it is conceded that bilharziasis militates against a condition of optimum health and represents a steadily increasing menace.

In the rain-forest zone of natural endemicity for bilharziasis mansoni in the southern Sudan, the disease, formerly mild, has already been increasing in incidence and severity and will continue to do so as a result of the planned economic development and the ensuing concentration of population. As bilharziasis mansoni is a more disabling disease than bilharziasis haematobia, the author thinks that the situation might become grave; close observation of developments, a study of the major sites of pollution and infection in these areas with a view to possible prophylactic measures, and an intensification of human treatment, are advisable.

With regard to Darfur and Kordofan—that is, the steppe-belt zone of marked natural endemicity for *S. haematobium*, where infection is acquired seasonally and considered to be benign—the author thinks it possible that the situation may remain more or less static because social or economic factors likely to cause deterioration do not seem to exist; nevertheless, the problem in these areas, with an estimated 17% incidence in the 2 million inhabitants, is not negligible.

Bilharziasis, predominantly *S. haematobium* infection, is so far only feebly endemic in the other areas of rainfall agriculture in the Sudan;

the disease has only recently advanced to Kassala Province in the east, where agriculture by irrigation is obtaining more importance; the progress of the disease should be carefully watched, and every attempt made to institute early control both of the snail and of the human vectors.

It is suggested that, in the sub-arid zones of predominantly natural endemicity, the fencing of watering-places be extended and that, instead of the usual pier, from which water is drawn, hand-pumps with floating inlets be installed. The more important snail foci of these regions should be investigated and treated by suitable methods. In the irrigated areas, bilharziasis is steadily gaining ground. In view of this state of affairs, both in the natural and man-made bilharzial areas of the Sudan, it is thought that the situation demands the establishment of specialized bilharziasis treatment units capable of dealing with a larger number of people than can be covered by the existing hospitals and dispensaries.

With regard to the Gezira, it would seem that 25 years has not been a long enough period to show the full cumulative effects of bilharziasis. Davey & Gordon [27] pointed out that the density of vector snails is such that, despite their low infection-rate (average: below 1%), the infection of all persons using canal water over a long period may be expected. It seems that this has not yet taken place. The human incidence quoted by Stephenson,[90] after a careful study of a restricted area of the Gezira, was 30%. If the figures of Greany,[40] which apply to a quarter of the population, distributed over the area, are taken as a basis of calculation, an equal haematobia and mansoni incidence of 9%, with an overlap of 3%, can be said to amount to a total overall incidence of 15%, which approaches the 17% quoted by Davey & Gordon. More exact methods of diagnosis than it was possible to apply might have revealed a somewhat higher incidence. Greany's study, however, indicated that as yet the Gezira is not as highly infected as some of the surrounding areas, since comparison of the incidence-rate, measured in about 10 000 relatively recent settlers and in about 50 000 older settlers who had been examined under similar circumstances, revealed significantly higher rates among the newcomers. As regards intensity of infection, however, the author is inclined to think that the worm-load, in the latter group, is lighter.

Although the lower snail counts obtained by Stephenson [90] in the continuous-flow area of Abdel Magid—which was then relatively new—have not been corroborated by Greany [40] at a later date, it is believed that the change from night-storage of water to continuous-flow would be decidedly advantageous from the point of view of weed and snail control, as well as from that of the diminution of silting. In fact, the newly-added areas have been projected on a free-flow basis; the cost of wholesale change is, however, considered prohibitive. An alteration of canal construction at bridges, siphons, and regulators, so as to avoid the backwaters at the narrowings, which form ideal snail breeding-places, is advisable.

As pointed out by Davey & Gordon, the irrigation system, which has brought wealth to the community, has also resulted in the deterioration of health standards. Their contention that the rectification of this state of affairs should be the concern not only of the health authorities, but of all departments concerned in the advancement of the Gezira scheme, is upheld by the author. Although the general study programme recommended by these authors is excellent, he does not think that bilharziasis control measures, especially those related to mass population survey and treatment, should be delayed until the completion of such extensive research. In fact, it might be desirable to extend the programme at present introduced in one-fifth of the Gezira to the entire area and to institute, as far as possible, the measures outlined under the section entitled General Discussion (see page 103), especially those referring to environmental sanitation, snail control, and health education. Prophylactic measures in the irrigated areas and other bilharziasis regions might be financed from the agricultural income derived from the former areas.

It might also be advisable to follow up, in a chosen pilot area, Archibald's suggestion [8] of planting *Balanites aegyptiaca* (" heglig ") on the banks of watering-places. The tree flourishes in rainy as well as in arid regions and grows throughout tropical Africa, Arabia, Egypt, and Palestine. It fruits abundantly for six months and its berries, kernel, bark, roots, and branches all contain a substance which is lethal to molluscs, miracidia, and cercariae, but does not impair the potability of water. Archibald suggested dense afforestation of ponds and " khors " adjacent to villages and of streams, especially the blind ends, as well as the treatment of stagnant water collections by emulsions made from the berries.

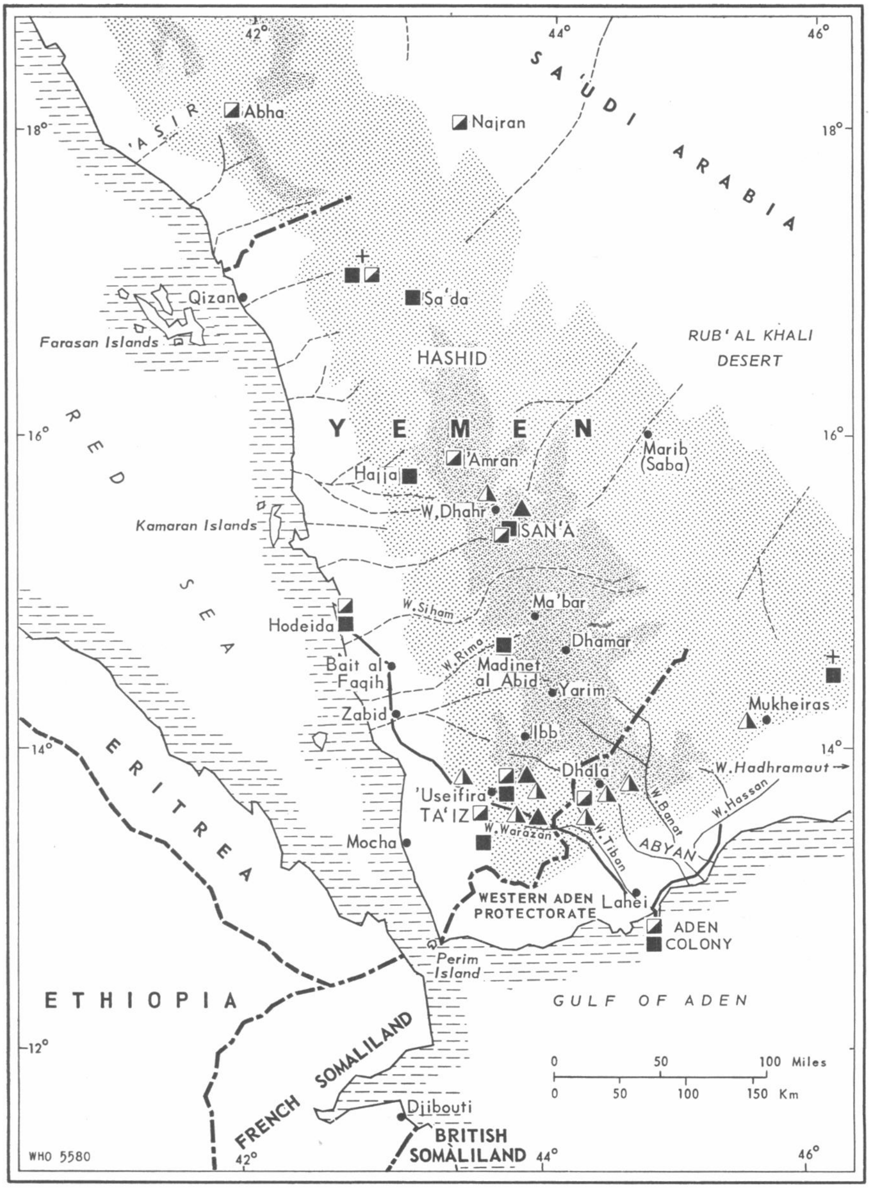
YEMEN

General Description

The Kingdom of Yemen (see Fig. 9), independent since the withdrawal of the Turks in 1918, occupies about 200 000 km² (77 000 square miles) in the southwestern corner of Arabia. With its 500 km (310 miles) of coastline (from latitude 13°N to 18°N), facing Eritrea, it is a country belonging to the southern Red Sea group. It is bounded, on the south, by the Aden Protectorate and on the north by ‘Asir, Sa‘udi Arabia, while in the east it merges into the Rub‘ al Khali, the great southern desert of Arabia. The population is estimated at about five million. The country is a relatively closed region into which foreigners are not encouraged to enter.

With regard to general topography, the entire shelf of the Arabian plateau tilts gradually towards the Persian Gulf while its high western rim,

FIG. 9. YEMEN



■ *S. haematobium*

◪ *S. mansoni*

+ Reported from area

▲ *Bulinus (Bulinus)* spp.

◭ *Biomphalaria* spp.

1000-2000 m (3300-6600 feet)

Above 2000 m (6600 feet)

—— Ground travel route

crowned by ridges and volcanic cones, falls abruptly to the Red Sea in a series of step faults. The section of the western Arabian highlands lying south of the Hejaz—namely, the region of 'Asir and the Yemen—forms a geographical unit presenting closely similar features. These tablelands also form the counterpart of the Ethiopian plateau rising on the western side of the Red Sea rift.

The uplands of southern Arabia, which, lying in the path of the south-west monsoon, have the highest rainfall of the peninsula, form part of the verdant fertile regions formerly known as " Arabia Felix " and harbour about half of the total population of Arabia. The core of these highlands is formed by a tilted and dissected plateau, most of which lies between 2000 m and 3000 m (6600-9900 feet), but whose highest peaks rise to over 4000 m (13 200 feet). The region is under a climatic regime of summer rainfall, with an average of at least 500 m (20 inches) over most parts of the plateau, but attaining 1000 mm (40 inches) in the more elevated sections. There is a minor rainy season in spring (March-May) and a major rainy period from July to September. Subsoil water is abundant and numerous hot and cold springs exist, especially on the slopes.

A number of short but fast-flowing streams descend seawards in valleys cutting deeply into the western scarps, but they usually fail to cross the coastal plain. The streams flowing eastwards from the watershed are fewer and follow the more gently dipping slope before they peter out in the sands of the desert.

Because of the difference in altitude, the region can be divided into a series of strips, corresponding to a succession of climatic zones and running, in the main, parallel to the coast of the Red Sea. The coastal plain, or Tihama, is a thinly populated, hot, and barren zone with scanty rains, falling mostly in winter, and insufficient vegetation even for grazing. The piedmontite zone supports a small semi-pastoral population. A tropical, largely African fauna and flora prevail in the deep valleys leading to the middle heights.[a] At about 1000 m (3300 feet), Mediterranean plants make their first appearance. At 1500 m (4900 feet), cereals, fruits, vegetables, and coffee are grown on skilfully terraced valley slopes; this zone, with its rich volcanic soil, is the most productive zone of the Yemen and supports about 60% of the population. On the temperate highland plateau, wide areas are extensively cultivated, frequently being watered from deep wells and cisterns. Here frost and snow are not uncommon in winter, while in summer the temperature usually does not exceed 28°C. In the eastern and lower inland regions, the remains of magnificent irrigation works and the ruins of ancient settlements testify to the prosperity of these parts before the advent of drier conditions.

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[a] " Middle heights " indicates elevations of about 1000 m, " highlands " indicates elevations of about 2000 m.

Geographical Distribution of Bilharziasis

Review of available data

According to Sarnelli,[81] vesical bilharziasis has been long established in Yemen and is well described in mediaeval books of Arab medicine. The author believes that bilharziasis may well have existed from time immemorial. If introduction from Africa need be postulated, opportunities have certainly been manifold and constant. It is claimed by some that Yemen formed part of the famous Land of Punt, a region which handled the commercial traffic between southern Asia and Egypt from the third millennium B.C. onwards. It is also known that Egyptian trading and plant-collecting expeditions reached the Land of Punt. Expeditionary forces from Egypt were sent to Yemen at least twice in later periods: the first reached Marib (the former Saba or Sheba) when Augustus, in 24 B.C., wished to open the riches of the Sabaean Kingdom to Roman trade; the second was sent in the 12th century by Saladin, under the command of his brother, who subdued the country, making his capital first in Zabid and later in Ta'iz.

Communication and trade with East Africa and Ethiopia existed from the earliest times. South Arabian peoples settled in the Abyssinian highlands before recorded history. In the 4th and also the 6th centuries of the Christian era, the powerful Aksumite kings of Ethiopia conquered and for a time ruled Yemen, making San'a their capital. Contacts between the two continents have never ceased, and today the population of the lowlands and the foot-hills of Yemen shows a strongly African admixture of blood. In Islamic times, the stream of pilgrims from various parts of Africa to the Hejaz may have been a further source of dissemination for the whole of Arabia.

The first indication in modern scientific literature of Arabia as a possible site of *S. haematobium* infection was given in 1887 by Hatch,[45] who described bilharziasis haematobia cases from India among Moslems who had made the pilgrimage to Mecca. Analogous observations were made subsequently by a number of authors from other countries.

Yemen was first incriminated in 1923 by Greval,[42] who saw bilharziasis cases at the Indian Station Hospital in Aden among Yemenites who had never left Arabia. He reported 2 haematobia cases, one in a Yemeni from Dhala, (Western Aden Protectorate) and the other from " El Usmat " (? El'Useimat), Hashid district, in the Yemen highlands north of San'a. He also reported 2 mansoni cases, one originating from " Usafi " (?'Useifira) near Ta'iz and the other from Makatira, west of Ta'iz; this constitutes the first record of bilharziasis mansoni in Asia.

Malchi,[61] in 1924, reported 2 bilharziasis mansoni cases in Yemenites, at Tel Aviv. Except for one other case of bilharziasis mansoni in an Arab coming from Yemen, which was reported in 1936 by Bacchelli,[11] from Italian Somaliland (Somalia), the records for the next two decades deal with bilharziasis haematobia, the diagnosis of which presents fewer difficulties.

Thus Rizzo,[79] in 1927, reported infection in a Yemenite immigrant to Cyrenaica. Mattei,[66] in 1931, recorded a case met in Italian Somaliland (Somalia), who had acquired the disease in Yemen. Veneroni,[96] in 1933, reported a haematobia incidence of 9.5% in Yemen lowlanders.

The first detailed account of the occurrence of endemic vesical bilharziasis in Yemen was made by Sarnelli [81] in 1935. He reported that the disease was very common in San'a and perfectly familiar to the people, who called it " bôl ed-dèmm " (bloody urine) or " dà ed-dìb " (disease of the wolf). According to Sarnelli, " it is in the order of the day to hear from people of the city that they emit a little blood after micturition ".[a] He determined the disease microscopically and affirmed that it occurred in patients who had never left San'a or the villages on the plateau surrounding the capital. He also reported *Bulinus* snails proper as very common in the streams, cisterns, and large irrigation water-storage basins of the region, especially at the time of the great summer rains, when they abound in the vegetation at the edge of these water collections. Sarnelli diagnosed about 200 cases in two years, a number he considered low in view of the widespread nature of the disease, and stated that the people did not pay great attention to it. He also stated that some of his patients had acquired vesical bilharziasis in the middle and lowland zones.

He further described the multiple and constant human movements taking place between Yemen and various Italian colonies, especially Eritrea, but also Somalia, Cyrenaica, Tripolitania, and Italy itself, stressing the danger of the introduction of vesical bilharziasis from Yemen to these regions directly and indirectly, and of its further spread and dissemination: " If we imagine our colonies as one intercommunicating system, it will not be difficult to imagine Yemen as ' interpolated ' like a ' relais ' or amplifier in an electric network, with the function of reinforcing the capacity of the whole ".[b]

In 1939, Petrie [74] mentioned that bilharziasis (unspecified, but presumably haematobia) was common in several districts of the most fertile but least healthy middle heights of Yemen; he stated that from these bilharzial areas originated most of the cases of vesical calculi commonly seen in Yemen. According to that author, the many cases of bilharziasis seen in San'a all came from the lower altitudes, especially from Madinat al 'Abid (Wadi Rima). He further suggested, as did Sarnelli,[81] also, that the various

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[a] " In città è all'ordine del giorno udite di gente che emette un po' di sangue dopo la minzione."

[b] " Rappresentandoci l'insieme delle nostre Colonie come un sistema simile di interferenze e di intercomunicazioni, non ci riuscirà difficile immaginarci lo Yemen 'interpolato' o inserito, come un *relais*, o soccorritore, in una rete elettrica, il quale intervenga a rafforzare la funzione dell'assieme."

much frequented thermal springs of Yemen might play a role in the transmission of the disease. The arid coastal zone is not thought to offer favourable conditions for its propagation.

In 1941, Connolly [19] recorded the occurrence of *Biomphalaria arabica* in the northern mountains of Western Aden Protectorate, in Ta'iz region and in Wadi Dhahr near San'a, and that of *Bulinus truncatus* in the Yemen highlands, while shells only of that species are reported from Hadhramaut.

Abdel Azim,[1] quoting data obtained from the Arabian American Oil Company, in Dhahran, during his bilharziasis survey in Sa'udi Arabia in 1951, reported that, of 83 bilharziasis cases accidentally discovered among the workmen of the company, 10 originated from Yemen (7 mansoni and 3 haematobia), while 10 mansoni cases came from Aden Protectorate and another 20 from 'Asir, of which 10 were from Najran, at the very borders of Yemen.

In the same year the United States Naval Medical Research Unit No. 3 (NAMRU-3), Cairo, Egypt, sent a medical mission to Yemen. The mission visited the regions of Ta'iz, San'a, and Hodeida, situated in the middle heights, the highlands, and the arid coastal plains, respectively. The findings of the mission as regards bilharziasis (Kuntz et al.[54] and Kuntz [53] and personal communication) are summarized in the following paragraphs:

S. mansoni was found to be highly endemic in Ta'iz (56% of 73 persons examined), while the incidence in the children of this same group was even higher—70% of 34 schoolchildren. *Biomphalaria* snails, all uninfected, were found in various ditches and slow-running streams north and north-east of the city, as well as in an open storage basin in the King's garden at 'Useifira, one mile (1.5 km) north of Ta'iz, where the disease had been contracted by bathers one year previously. The only infected *Biomphalaria* snails were found in the ablution pools of two mosques. In one of these, 35% of 75 *Biomphalaria* were highly infected with cercariae of *S. mansoni*. These snails were found in the dark internal ablution chambers, in the stone conduits, and in the open-air basins. The importance of the mosques in the transmission of bilharziasis mansoni in that town and the highly effective life-cycle potential they represent was stressed. The incidence of *S. haematobium* amounted to 10%, but *Bulinus* snails were not found in the town or its immediate vicinity.

With regard to the highland region around the city of San'a and in Ma'bar, bilharziasis mansoni was found only in 18% and 4%, respectively, of the persons examined, most of whom had visited the middle heights towards Ta'iz. No ova of *S. haematobium* were found in 96 persons examined. Both *Bulinus* s.s. and *Biomphalaria* were found in drainage ditches and small streams in " wadis " (valleys). Various cisterns contained *Bulinus*, but only shells of *Biomphalaria*; *Bulinus* snails were also found in a mosque in Wadi Dhahr, north of San'a. Puzzled by his failure to find either *S. haematobium* cases or infected *Bulinus* s.s. in an area where Sarnelli [81] had reported the disease as so prevalent, Kuntz questioned its presence there.

Only a few cases of bilharziasis were found in Hodeida (7% mansoni and 2% haematobia). All of these had recently come to the district, either from other parts of Yemen or from beyond its borders, and 3 haematobia cases out of 4 were reported to have come from Eritrea. No snails were found in the basins of several mosques at Hodeida.

In general, the presence of bilharziasis mansoni and haematobia in Yemen is attributed to the continual migration of infected persons from Eritrea and other countries of East Africa into Yemen, while numerous cases of *S. haematobium* infection are stated to have originated in Eritrea (see page 92).

Survey

The author was informed by Dr Toffolon, the resident physician at Ta'iz, that he had been seeing mansoni cases there since 1946 only and that he had never met any from the Tihama. With regard to *S. haematobium*, he had seen cases since 1939, many of whom had come from Turba, a village in the Hojjariya region, about 110 km (70 miles) by road south-west of Ta'iz, and some of whom had come from the Tihama and from Hajja, about 80 km (50 miles) north-west of San'a. This information confirmed that previously obtained by the author from the Yemeni agent in Asmara, Eritrea, a native of Hajja, who testified to the common occurrence of haematuria there. The prevalence of haematuria and bloody stools in the Hajja and Sa'da regions in the north was also known to the Qadi el 'Arshi, a Yemeni notable who had been governor of the northern " liwas " (provinces) for a number of years.

Southern Yemen (middle heights and Ta'iz region). All waters encountered en route between Aden and Hodeida via Ta'iz were examined. *Bulinus truncatus* and *Biomphalaria* were found beyond the Yemeni customs station at Rahda, near Badu village, in the Wadi Warazan which contained a stream about 8 m (26 feet) wide at the time of the survey, flowing between grassy banks over a bed of pebbles, from Yemen into the Sultanate of Lahej. No snails were found in the fertile Wadi Halhal, where three harvests are obtained annually.

The ancient town of Ta'iz, the provisional capital of Yemen and residence of the present King and Imam, has a population of 3000-4000 and is situated at about 1400 m (4600 feet) on the flank of Jebel Sabir, a large and fertile mountain mass from which innumerable streams descend towards the city. A stream, supplying the Muzaffar mosque, was examined for snails; large numbers of *Biomphalaria* were found in an open conduit, about 30 cm (12 inches) wide and 10-15 cm (4-6 inches) deep, running at roof level before flowing into the ablution pools inside the mosque. No snails were found in either the basins reserved for ritual ablutions or those reserved for washing after urination or defecation. *Biomphalaria* snails were also obtained in Wadi Hedran, west of Ta'iz, in a small stream resembling an Egyptian irrigation canal. Various other streams, about 2 km (just over 1 mile) north of the city, were also surveyed and in 'Useifira es Sufla (Lower 'Useifira) *Biomphalaria* were found in a cemented basin.

At the public school, 30 urine samples were examined in the 10-21 age-group. The only case of bilharziasis haematobia had come to Ta'iz one month previously and was a native of San'a who had spent two years in Hajja. Of 20 stools examined, 14 were positive for *S. mansoni* (70%). The infected boys had stayed in Ta'iz from one month to 10 years but had all originally come to Ta'iz from other places—namely, Sabir, the mountainous tract south of Ta'iz; Hojjariya, to the south-west; Jebel Habash and El Ruba'in, to the west; Hoban, to the east; and Ibb, Hebeish near Ibb, Dhamar, and Hajja, to the north. Infestation with *Ascaris* was also very common (15 cases).

San'a region (the central highlands). San'a, the largest of the highland towns of Yemen and for many centuries its capital, has a population of about 50 000. It is situated at about 2400 m (7800 feet) in the centre of a district which owes its fertility to a thick bed of wind-formed spongy soil that retains a sufficient amount of rain in its deeper layers. *Bulinus truncatus* snails were located in Majil el Khalifa ("majil" = cistern), a round cemented brickwork basin, 4 km (2.5 miles) north of San'a, on the way to Wadi Dhahr, containing abundant aquatic vegetation (*Potamogeton*, algae). *Biomphalaria* snails were found in Asfaya village, at Wadi Dhahr, in a stream with a muddy bottom and grassy banks, which enters a garden near a mosque.

At San'a, 30 urine samples and 19 stools were obtained from the pupils and staff of the secondary school and the orphanage school, both of which draw pupils from a large area; two infections with *S. mansoni* and five with *S. haematobium* were found, of which one was a double infection, as is shown in Table XXII.

Hodeida and lowland zone. Hodeida, at present the most important of the three seaports of Yemen, has a population of about 40 000. The water systems of a number of mosques were examined. The supplying wells, channels, and basins were all negative for vector snails. The water is brackish and, since it is usually changed only once every 4-6 months, is slimy and green with algae. The drinking-water wells, between 12 m and 15 m (40-50 feet) deep, were equally negative.

At Hodeida, 30 urine samples and 9 stools were obtained from school-boys between the ages of 9 and 16 years; all of these proved negative for bilharziasis. The urine samples of 5 adults from the staff of the school and other adults were also negative, while 2 out of 3 stools furnished

TABLE XXII. PLACE OF ORIGIN OF INFECTED PUPILS AT SAN'A, YEMEN

Schistosoma		Age (years)	Town of origin	Travelling distance (days)* and direction from San'a	Length of residence in San'a (years)
haematobium	*mansoni*				
	1	19	Beni Matar	1, west	8
1	1	15	El Sidda	5, south	3
1	1 (same)	16	Usab	7, south-east	7
1		15	'Amran	1, north	
1		12	San'a		
1		10	San'a		

* As a result of the lack of adequate maps, the author had to follow the ancient method of evaluating distances in days' journeys. An approximate idea of one day's journey may be obtained by referring it to the distance San'a-'Amran, which is given as about 50 km (31 miles) on the map, but such estimates are far from constant, especially in mountainous terrain.

revealed ova of *S. mansoni* (67%). One of these cases was the school servant, 27 years old and coming from Bakal village in Wadi Rima; the other was the customs official, a young man of 23 and a native of Samma, who had lived in San'a from his 10th until his 20th year and had then been in Ta'iz for one month before coming to Hodeida three years earlier.

Several mosques in Bait al Faqih and the waters of Zabid were examined

TABLE XXIII. STOOL* AND URINE EXAMINATIONS IN YEMEN (MAINLY SCHOOLBOYS)

Locality	Age (years)	For *S. haematobium*		For *S. mansoni*	
		examined	positive	examined	positive
San'a					
secondary school	15-35	11	2	10	2
orphanage school	9-35	19	3	9	0
Ta'iz					
public school	10-21	30	1	20	14
Hodeida					
primary and secondary schools	9-16	30	0	9	0
staff and other adults	23-30	5	0	3	2
Total		95	6	51	18

The individuals examined came from various parts of the country.

* Other intestinal parasites found among the 51 stools examined were: 23 *Ascaris*, 1 *Hymenolepis*, and 1 *Trichocephalus*.

for snails, with negative results. Towards higher ground, *Biomphalaria* snails were found in Wadi Hedran, as has been already mentioned.

Aden Protectorate. It was learnt in Aden that both forms of bilharziasis have been appearing regularly in the Aden hospitals, introduced from the

TABLE XXIV. FRESHWATER GASTROPOD MOLLUSCS COLLECTED IN THE YEMEN

Serial No.	Place of collection	Description	Species
	Ta'iz region		
19	Wadi Warazan, near Badu village, on Aden-Ta'iz track	stream, 8 m (26 feet) wide, sand and pebbles, grassy banks	*Bulinus truncatus* *Biomphalaria* sp. *Lymnaea natalensis* *Bulinus forskalii* *Melanoides tuberculata* *Cleopatra bulimoides*
20	Ta'iz; Muzaffar mosque	stone channel, 30 cm (12 inches) wide, 10-15 cm (4-6 inches) deep	*Biomphalaria* sp.
24	Wadi Hedran, west of Ta'iz	stream resembling Egyptian channels	*Biomphalaria* sp. *Melanoides tuberculata* *Viviparus* sp.
25	'Useifira es Sufla, 1 km north of Ta'iz	cemented basin	*Biomphalaria* sp. *Melanoides tuberculata*
	San'a region		
21	Majil el Khalifa, on the way from San'a to Wadi Dhahr	*Potamogeton*, algae (Majil = cistern)	*Bulinus truncatus* *
22	Asfaya village, Wadi Dhahr, 7 km north from San'a	stream; mud bottom, grassy banks	*Biomphalaria* sp. *
	Hodeida		
23	Various mosques and water collections	channels, basins, etc.	*Melanoides tuberculata*

* See Fig 10, and section entitled Malacological Notes, page 93.

NOTE:

(1) All snails listed above seem very close to the Egyptian types, with the exception of the *Viviparus* sp.

(2) The *Bulinus* s.s. of the Yemen (and of the whole Ethiopian and Red Sea region) are classified under *B. sericinus* Jickeli by Mandahl-Barth (personal communication). Both Blair (personal communication) and Connolly [19] of the British Museum, identify *Bulinus* from Yemen as *B. truncatus*, Connolly [19] seeing no cause to consider a series collected in the Yemen as "distinct from the variable Egyptian species".

(3) The Yemen race of *Biomphalaria*, which the author would have called *boissyi* (Abdel Azim [1] states that in Sa'udi Arabia this snail resembles *boissyi*), and which, according to Kuntz,[53] was identified as *Biomphalaria boissyi arabica* by Dr J. Bequaert of the Museum of Comparative Zoology, Harvard University, Mass., USA, has been identified by Mandahl-Barth (personal communication) as *Biomphalaria rüppellii*, by Blair (personal communication) as a form close to *boissyi*, and by Connolly [19] as *Biomphalaria arabica* (Melvill and Ponsonby, 1896), with the remark that the shell very closely resembled that of several African species.

(4) *Lymnaea natalensis* Krauss, 1848, is considered synonymous with *L. cailliaudi* Bourguignat, 1883.

hinterland, including Yemen. Two hospitals were visited and 4 cases of bilharziasis mansoni were found. These originated from the upper Wadi Tiban, from Tor el Baha, on the Yemeni border, from Yeshbum in Wadi Azzan, and from Um Turba north-west of Am Shat.

The government-sponsored Abyan agricultural project, an area of about 300 km² (115 square miles) situated some 80 km (50 miles) north-east of Aden, was also visited. In this area the Abyan Committee, operating under the British Colonial Office, is bringing back under cultivation land which has been abandoned on account of feuds and general unrest; the cultivators work on a share-cropping basis with the Government. The project preserves and utilizes, by suitable damming and canalization, the flood waters draining from the highland region of Yarim in Yemen through the Wadi Banat, and from the Mukheiras plateau through the Wadi Hassan, etc., during the July-September rains. These wadis have permanent streams only in their upper courses. The project has now about 300 km (185 miles) of canals. With adequate watering, the soil is very productive and gives large crops of cotton, sugar-cane, sorghum, sesame, etc. In Jofàr, 90 000 bales of cotton were grown in 1951. In the Batis area, 150 acres (60 ha) produced 300 tons (3050 quintals) of sugar. Two ginning mills and a factory for refining sugar and making alcohol are planned. The area now has a population of 20 000 but the project is capable of considerable further extension and could without difficulty bring more land under cultivation than could be managed by the existing population.

The author examined all streams encountered, finding only *Melanoides tuberculata* in the Wadi Hassan. According to Dr Gurney of the Scottish Mission Hospital at Jofàr, this is the only species of aquatic snail present. The region does not seem to furnish, at present, favourable conditions for the establishment of vector species, of which *Biomphalaria* has been shown to occur in the mountainous hinterland by Connolly [19] (see Fig. 9, page 82).

Results of the urine and stool examinations made in Yemen are summarized in Table XXIII, and a list of the freshwater molluscs collected is given in Table XXIV.

Discussion

It would seem that both *S. haematobium* and *S. mansoni* are widely spread and firmly entrenched in the mountainous regions of south-western Arabia, from Aden Protectorate to 'Asir, including the whole of Yemen. It also appears that haematuria is well known in diverse parts of Yemen, while snails of the subgenus *Bulinus*, the unquestioned, though undemonstrated, vectors, are also known to occur at medium and at high altitudes. Intestinal bilharziasis, though not recognized by the population as a disease separate from the dysenteries, has been shown to be prevalent in the southern parts of the country and to occur in central Yemen as well as in 'Asir; although not specifically reported from the intervening northern section of Yemen, there is no reason to suppose that it is absent. The same is true of *Biomphalaria*, the ascertained vector.

Despite the gradual drying-out of Arabia, as illustrated by the finding of fossil and subfossil *Bulinus* s.s. and *Biomphalaria* snails in the Rub'al Khali desert by Philby,[75] these snails still find excellent habitats in the mountainous regions of Yemen.

The author, who was more fortunate in finding haematobia cases in San'a (17% of 30), does not share Kuntz's doubts as to the endemicity reported in that region by Sarnelli; failure to find infected snails even in endemic areas is not unusual. With regard to the occurrence of *S. mansoni* in the highland regions, it can be said with certainty that cases are found and that suitable vectors are present.

Bilharziasis seems to be more prevalent in the middle heights than in the highlands of Yemen; this greater occurrence, though understandable in view of the warmer climate and greater abundance of water, contrasts with conditions prevailing for *S. mansoni* in Eritrea, which is the topographical and climatic counterpart of Yemen. There, bilharziasis mansoni is believed to have become endemic only in the highlands, at altitudes ranging around 2000 m (6600 feet). A possible explanation of the situation in Eritrea might lie in the assumption that the foci on the high plateau are of recent and accidental origin and that this disease has not yet had time to expand and entrench itself in optimum habitats.

With regard to the tropical arid coastal region of Yemen, all cases found seem to be imported. Having discovered no indication of endemicity of bilharziasis haematobia in Eritrea, the author is not convinced that the 3 haematobia cases described by Kuntz et al.[54] from Hodeida, and reported to have come from Eritrea, had actually acquired the disease there, even if they had visited that country, nor does he think it possible that numerous cases of infection by *S. haematobium* could have originated in Eritrea as stated by Kuntz.[53]

Although the importance of the bilharziasis situation as such cannot be ignored, its relative importance is not so great in a country which has more than its fair share of disease and as yet no adequate health organization; the only medical care available for five million people is administered by a handful of doctors and only 3 hospitals. Mediaeval conditions have survived to this day and practically all modern social and health developments still await introduction. The system of sewage disposal in the large cities is primitive. Solid excreta are collected in special chambers on the bottom floor of each house. The waste water and urine flow from the upper storeys in special plastered grooves on the outside of the walls, to run openly in the streets. In most instances, the water-supply is led to the cities in open conduits, which are exposed to the grossest pollution.

In the course of time, the most pressing epidemic and endemic diseases, especially the sewage-borne diseases, will have to be attacked. Much could be done for bilharziasis control, in the initial stages of any general health campaign, by piping the water-supply, by removing the open sewers, and by rendering sanitary the mosque ablution basins, which play an important role in the transmission of bilharziasis and various other communicable diseases and also serve as very suitable breeding-places for mosquito larvae. It is believed that the suggestion of Kuntz [53] that either the ablution basins should be regularly drained or their water treated chemically, twice a year, would not be effectively carried out. However, the mosque water-supply system might be changed to advantage; piping and drainage as practised in Egypt is practicable and would be cheaper in the long run. The water-supply to Ta'iz is now piped, and an extension of this work to the mosques is possible and advisable.

The first necessity is to arouse goodwill and interest in public health among the general population and especially among those in authority. The people, though thronging round any doctor in the hope of obtaining relief from their various ailments, are handicapped by their background, and are not at present able to grasp the necessities of sanitation. There exists, above all, an urgent need for enlightenment and education.

MALACOLOGICAL NOTES

General Notes on African Freshwater Gastropods

Pilsbry & Bequaert,[76] discussing the remarkable uniformity of the African molluscan freshwater fauna as compared with the terrestrial fauna, and the poverty of genera and species in Africa as compared with the USA, have pointed out that differences are slight between the various river basins, certain species extending over immense areas, regardless of watersheds. This was stated to be especially true for a number of pulmonate gastropod genera, including *Lymnaea*, "*Planorbis*", "*Bulinus*", and "*Physopsis*", with the remark that many described species of this group were hardly separable, or at any rate showed extremely close affinities. This general homogeneity of the freshwater molluscs is attributed to the possibilities of easy and frequent migration between the different river systems which prevailed in the various humid pluvial periods during and after the pleistocene—that is, chiefly after the species had already become differentiated into their present shapes.

The equally close affinities of the representatives of these pulmonates in the Arabian peninsula with the African forms have been pointed out repeatedly. Geographical connexion with Africa had, however, ceased, except in the northernmost part, long before the pleistocene. Whether this may be taken as a sign that differentiation leading to permanent changes may take much longer in this group of animals than the time which has elapsed since the pleistocene, or whether one should rather assume later introduction or migration, does not seem clear. It is, however, the unanimous opinion of scientists dealing with the subject of bilharziasis and its vectors in Africa that much detailed study of material will be necessary to clarify the confusion which has long reigned as regards the nomenclature of the molluscan groups concerned.

This confusion is easily understandable because, on the one hand, the classical specific descriptions of the past were frequently made on the basis of the shell alone, sometimes from single shells obtained at second hand, and by zoologists of many different countries; while on the other hand, it is a well-known fact that the shape of the shell readily exhibits changes as a result of altered ecological conditions, that the proportions of young specimens usually differ quite markedly from those of adults, and that even series of adult individuals from the same habitat show considerable variability. In the family *Planorbidae*, this has led to the creation of artificial species, based on mere detail of shell conformation, and also to considerable duplication, synonymous species being known under different names in different countries. At the same time, the fluidity of various molluscan groups is such that many which are transitional forms between the recognized shell types, as described and exhibited in the museums of different countries, cannot be classified with certainty.

It is generally admitted that these problems would be solved by revision on the basis of anatomical detail, especially of the genital system. Anatomical studies may, however, raise new problems. Dr Mandahl-Barth (personal communication) referring to an anatomical study of *Bulinus* sp. from Uganda and Kenya, states: " I found that almost identical shells could belong to a different species and very different shells to the same species ".

From the view-point of medical malacology it would seem particularly useful if the biological characteristics, such as susceptibility to infection, were also to be taken into consideration; it is quite possible that there may be strains whose different reactions will not be evident from anatomical structure. It is not intended, however, to enter into the controversial subject of what characteristics should constitute a valid species, but merely to indicate the magnitude of the problem and the fundamental need for basic study.

It has already been indicated (see page 2) that the aquatic gastropods collected during the survey were divided, as far as possible, into corresponding portions, of which two were sent to two WHO snail-identification centres. It has been no surprise to find that the triple identifications (including those of the author) although basically in agreement, differ somewhat as to the specific naming, since Dr Blair's identification was based on literature and experience "south of the Sahara", and the author's on that of Egypt and the Middle East, while Dr Mandahl-Barth depended for identification not only on the appearance of the shell, but also on the region of origin of the specimens, stressing at the same time the need for anatomical confirmation, especially with regard to the multiform genera *Biomphalaria* and *Bulinus*.

No comment beyond that already given in the lists for each territory (see Tables II, IV, VII, XIII, XV, and XXIV) is considered necessary with regard to the groups of aquatic molluscs other than those including the vectors of bilharziasis. The two subfamilies in question, the *Planorbinae* and *Bulininae* are discussed in more detail in the following sections. A selection of planorbine and bulinine snails from each of the countries visited is shown in Fig. 10.

Subfamily " Planorbinae "

In present-day malacology [a] the familiar but overcomprehensive generic term *Planorbis* has been reserved for a European genus which does not occur in Africa proper. Only one species of Mediterranean distribution, *Planorbis philippii*, occurs in northern Africa. Formerly, the African representatives of other planorbid genera—*Anisus*, *Gyraulus*, and *Segmentina*—have also been referred to as *Planorbis*. None of the above snails are known to have any importance as vectors of bilharziasis; they are small and easily recognized by their flatness in relation to their diameter. The larger globular planorbids, of which Schwetz [86] writes: " It is more than probable that all African types are susceptible to infection with *S. mansoni* and capable of its transmission " [b] had also been ranged formerly under *Planorbis* proper. Today, malacologists follow Connolly [18] in adopting *Biomphalaria* Preston, 1910, as the valid generic name for the group. The anatomy of some members only of the group has been investigated.

The author collected *Biomphalaria* from all the countries visited except Somalia, where the snail is supposed not to occur. He demonstrated for the first time its presence in British Somaliland.

The " species " quoted by various authors for the different territories surveyed are described in the following paragraphs :

For the Sudan, Archibald [7] in 1933 reported "*Planorbis*" *boissyi*, *pfeifferi*, *alexandrinus*, and "*herbeni*". (Pilsbry & Bequaert [76] gave *P. herbini* Bourguignat, 1883, as a synonym of *P. rüppellii* Dunker, 1848.) Diagnosis was based on small differences in diameter (1.5 mm for the first two as against 1.2 mm for the last two) and in the shape, thickness, rate of

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[a] A meeting of the WHO Study-Group on Bilharzia Snail Vector Identification and Classification, held in February 1954, drew up principles of classification and criteria for the identification of snail vectors of bilharziasis in Equatorial and South Africa.

[b] " Il est donc plus que probable que tous les Planorbes africains sont susceptibles de s'infecter de *Sch. mansoni* et de transmettre cette infection."

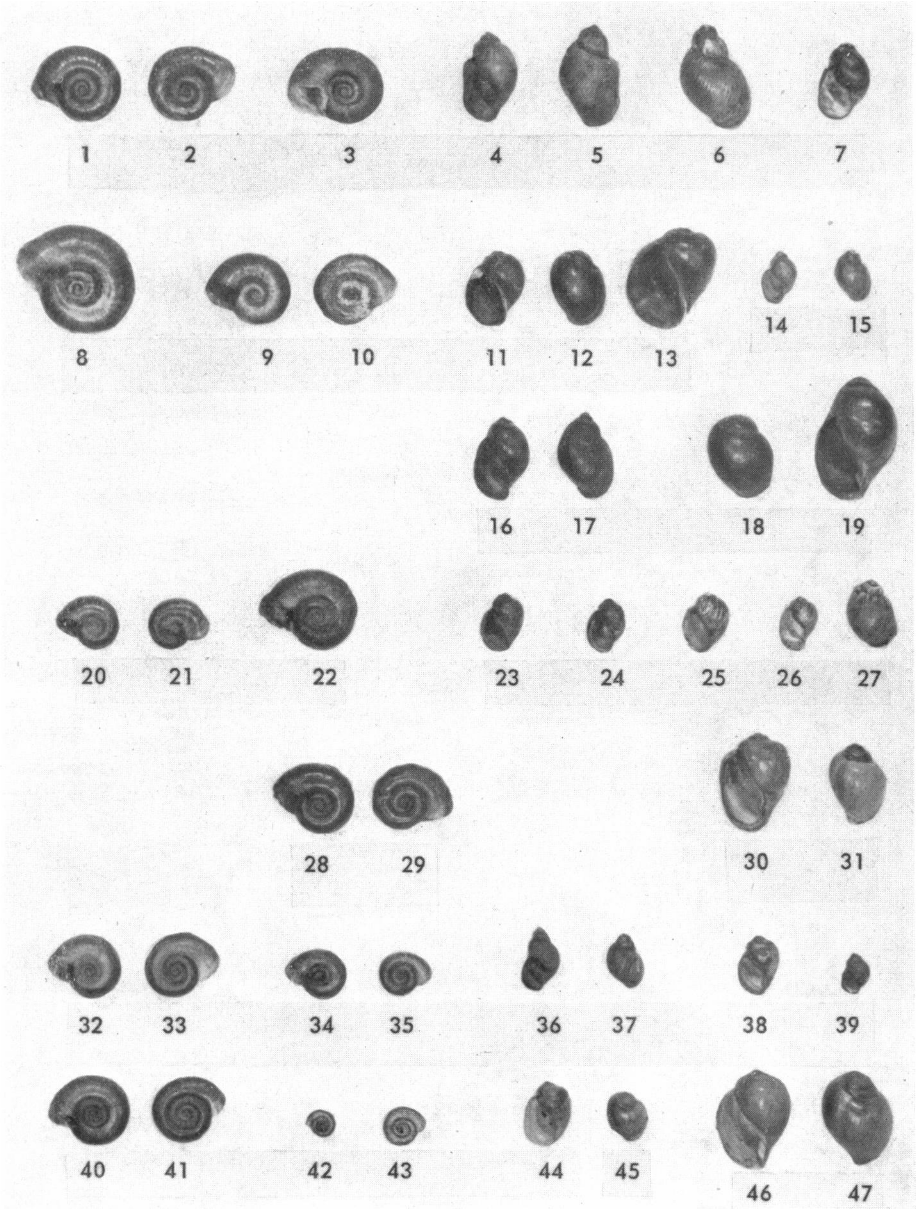
increase, and number of the whorls (4½-5), details which can be observed only in full-grown specimens. The present-day workers in the Sudan have been following the principle adopted in Egypt in naming the various forms found, which are all vectors of bilharziasis mansoni, *Planorbis boissyi*. Mandahl-Barth (personal communication) has recognized two classical forms in the samples from the Sudan sent to him: *Biomphalaria rüppellii* and *B. sudanica* (the latter larger and flatter than the former); he placed all other samples of *Biomphalaria* sent by the author under *B. rüppellii*. Other names quoted in the literature for the remaining territories are in the main " *Planorbis adowensis* " for Ethiopia and Eritrea, and *Biomphalaria arabica* for Yemen.

The differences between the shells of typical adult " *Planorbis* " *(Biomphalaria) adowensis* and *B. rüppellii* have been explained with great ingenuity by Giovannola.[37] With regard to the typical forms the author, who has had

Legend to Fig. 10

Snail No.	*Serial No.*		
		Eritrea	
1, 2	(3)	*Biomphalaria* sp.	— Cement channel, estate near Teramni
3	(2)	*Biomphalaria* sp.	— Adikuar stream, Adi Ugri
4, 5	(2)	*Bulinus (Bulinus)* sp.	— Adikuar stream, Adi Ugri
6, 7	(4)	*Bulinus (Bulinus)* sp.	— Akrea pond, Asmara
		Ethiopia	
8	(8)	*Biomphalaria* sp.	— Dukam river, Shoa Province
9, 10	(11)	*Biomphalaria* sp.	— Lake Tana at Bahrdar, Gojjam Province
11-13	(9)	*Bulinus (Bulinus)* sp.	— Lake Bishoftu, Shoa Province
14, 15	(12)	*Bulinus (Bulinus)* sp.	— Blue Nile, 3 km (2 miles) below outlet from Tana
16, 17	(18)	*Bulinus (Bulinus)* sp.	— Pond near Lake Aramaya, Harar Province
18	(11)	*Bulinus (Physopsis)* sp.	— Lake Tana at Bahrdar, Gojjam Province
19	(12)	*Bulinus (Physopsis)* sp.	— Blue Nile, 3 km (2 miles) below outlet from Tana
		Yemen	
20, 21	(25)	*Biomphalaria* sp.	— 'Useifira es-Sufla, cement basin near Ta'iz
22	(22)	*Biomphalaria* sp.	— Stream in Wadi Dhahr, Asfaya village, near San'a
23-27	(21)	*Bulinus truncatus*	— Majil el Khalifa (majil = basin), Wadi Dhahr road, near San'a
		British Somaliland	
28, 29	(28)	*Biomphalaria* sp.	— Stream near Laferug on Hargeisa-Berbera road
		Somalia	
30, 31	(34)	*Bulinus (Physopsis)* sp.	— Rain-water pool, 40 km (25 miles) from Mogadishu, on road to Villaggio
		Sudan	
32, 33	(46)	*Biomphalaria* sp.	— Dolga Canal, Abu 'Usher, Gezira
34, 35	(44)	*Biomphalaria* sp.	— Khor (spill) from Nile, Juba, Equatoria Province
36-39	(40)	*Bulinus truncatus*	— Stream in Jonglei Irrigation Scheme, Malakal, Upper Nile Province
40, 41	(40)	*Biomphalaria* sp.	— Stream in Jonglei Irrigation Scheme, Malakal, Upper Nile Province
42, 43	(43)	*Anisus* sp.	— Khor from Nile, Juba, Equatoria Province
44, 45	(46)	*Bulinus truncatus*	— Dolga canal, Abu 'Usher, Gezira
46, 47	(43)	*Bulinus (Physopsis)* sp.	— Khor from Nile, Juba, Equatoria Province

FIG. 10. SOME PLANORBID AND BULINID SNAILS * COLLECTED DURING SURVEY



* In view of the discrepancy of terminology, it has been preferred to leave most of the specific terms open.

The shells are illustrated natural size.

considerable experience with live planorbid material and has noted the great variations regularly met with in the large series collected in the field, as well as the changes occurring under laboratory conditions, appreciates the observation of Schwetz [85, 86] that the routine differentiations are too artificial, as also his plea for simplification of the systematics. It is indeed true that, should certain shell samples of various species be mixed, it would be next to impossible to separate them correctly.

Schwetz [85] has reported that he and Dr J. Bequaert, of the Museum of Comparative Zoology, Harvard University, Mass., USA, having examined the apparent morphology of a large recent collection of planorbids, and taken due account of the rules of priority, have agreed on a new and simplified terminology and classification, according to which the various large planorbids of Ethiopian Africa are not different species but only varieties of the oldest species described, *Planorbis alexandrinus* Ehrenberg, 1831, to be placed in the " subgenus " *Biomphalaria.* Among the five forms recognized and specially listed in the proposed classification, two will be of interest with regard to the samples dealt with in the present report:

(1) *Biomphalaria alexandrina* Ehrenberg, 1831, prevalent in Egypt and the Sudan as far as Bahr el Ghazal;
synonyms: *Planorbis boissyi* Potiez & Michaud, 1838
Planorbis sudanicus von Martens, 1870

(2) *Biomphalaria alexandrina* var. *pfeifferi* Krauss, 1848, common in central, eastern, western, and southern Africa;
synonyms: *Planorbis rüppellii* Dunker, 1848
Planorbis salinarum Morelet, 1876
Planorbis adowensis Bourguignat, 1878
Planorbis herbini Bourguignat, 1883
etc.

Certain anatomical differences, especially of the male genital system, have, however, been reported for a number of these forms.

Subfamily " Bulininae "

All African members of the subfamily *Bulininae* are now classified under one genus: *Bulinus* Müller, 1781. This genus now includes the forms which have been familiar, until recently, under two other generic names: *Physopsis* Krauss, 1848, and *Pyrgophysa* Crosse, 1879. *Physopsis* and *Bulinus* have been accorded subgeneric rank, while *Pyrgophysa* has become a species of the subgenus *Bulinus.*

Subgenus " Bulinus (Bulinus) "

The following comment refers to representatives of the subgenus *Bulinus (Bulinus)* in the regions surveyed, with the exception of one species, *Bulinus forskalii,* which is treated separately (see page 100).

The author follows Annandale [5] and later workers in believing that the multiform *Bulinus* proper of the Middle Eastern regions belongs to one species, in which case the oldest name, *Bulinus truncatus* Audouin, has priority. This belief is commonly shared by those who have extensively handled and observed the live material over any length of time, although it is not considered proven by all malacologists. The geographical distribution of the species includes the Sudan; it also extends to the Arabian peninsula, including Yemen, where it has been identified by Connolly [19] and others.

With regard to the various widely differing types collected during the survey in the Ethiopian highlands, including Eritrea, which do not all fall within the variation range commonly met with in the Middle East, the author would hesitate to give any opinion as to uniformity or otherwise. It might, however, be reasonable to assume that the situation on either side of the Ethiopia-Sudan border is similar, or that the upper Blue Nile basin has species identical with those further down in the line of drainage. In fact, bilharziasis, which is widespread in the northern and north-western parts of Ethiopia, including those areas draining towards the Nile, has been connected in the Italian literature with the common occurrence of *Bulinus* s.s.

Dr Mandahl-Barth (personal communication) has classified the various and multiform samples from the Ethiopian highlands, and also those of Yemen, as *Bulinus sericinus* Jickeli, 1874.

In Asmara (see Table IV, page 16), the local *Bulinus* were considered to be *B. raymondi*; these might possibly correspond to Annandale's *B. raymondianus* which is thought to be a species separate from the Mediterranean forms. As already indicated, these Eritrean *Bulinus* do not seem to act as vectors of bilharziasis haematobia, since the disease, despite opportunities, has apparently not become established.

Bulinus snails proper have not been found in British Somaliland or Somalia.

"Bulinus (Pyrgophysa) forskalii"

Pilsbry & Bequaert [76] state that no clear-cut division exists between the " subgenera " *Pyrgophysa* and *Bulinus* proper, since certain forms can be placed equally well in either of them. They also state that most of the species described are synonymous or mere variations of an extremely variable species.

Connolly [18] holds the same opinion, stating that although the typical elongate form of *Bulinus forskalii* Ehrenberg is "very distinct from typical *Bulinus*, every grade of intermediate occurs". *Bulinus forskalii* is widely distributed all over Africa and also occurs on the Arabian peninsula. The species has been incriminated as a vector of *S. haematobium* by Adams [2] in 1934, on the basis of successful experimental infection on the island of Mauritius, and has since been listed as suspect, especially when none of the usually accepted vector species has been located in a region endemic for bilharziasis haematobia. The vector capacity of *Bulinus forskalii* in continental Africa has been confirmed by De Meillon [28] who states that it is a very efficient vector and has been found to act so in the Union of South Africa.[a] As for various other regions of Africa, investigators have reported variable findings with regard to natural or artificial infection.

The author feels, however, that negative results should be viewed with caution, and that it is highly desirable to ascertain whether local varieties of this species are susceptible to, and can transmit, local or imported strains of the parasite.

The consultant was able to collect specimens of *Bulinus forskalii* from all the countries visited, except Ethiopia and Eritrea.

Subgenus " Bulinus (Physopsis) "

Connolly [18] in 1938 treated *Physopsis* Krauss, 1848, as a subgenus of *Bulinus*. The species are few and mostly ill-defined, some forms merging into *Bulinus* s.s. The author noted that young *Bulinus (Physopsis) africanus* Krauss in laboratory culture at Cairo were difficult to distinguish from *Bulinus* s.s., although this was not the case with adults.

Bulinus (Physopsis) africanus and *Bulinus (Physopsis) globosus* are the recognized vectors of bilharziasis haematobia in Africa south of the Sahara. Pilsbry & Bequaert [76] treated *Bulinus globosus (Physopsis africana globosa)* Morelet as a subspecies of *Bulinus africanus*, and attached little importance to the other varieties of *Bulinus africanus*. Blair (personal communication) includes *Bulinus globosus* in *Bulinus africanus*, together with all the forms intermediate between the two. Schwetz [86] considered *Bulinus globosus* to be a very minor variety of *Bulinus africanus*, stating that the only species which showed any real morphological differences was *Bulinus (Physopsis) nasutus*; he reported the latter species as a vector of bilharziasis haematobia in Uganda.

The author collected samples of *Bulinus (Physopsis)* from the southern Sudan, from northern Ethiopia (Lake Tana and Blue Nile), and from Somalia. The later were of a type somewhat resembling *Bulinus* s.s. *Bulinus (Physopsis)* is not known to occur in the other regions covered by the survey—namely, the northern Ethiopian highlands, including Eritrea, central and northern Sudan, British Somaliland, and Yemen.

Mandahl-Barth (personal communication) classified the samples from

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[a] Lately, it has been reported by the WHO Expert Committee on Bilharziasis [98] that the species is though to act as intermediate host in northern Nigeria. Quite recently, 2 *Bulinus forskalii*, collected from a canal north-west of Cairo, were found to contain haematobium-like cercariae in the laboratory of the Bilharziasis Control Section of the Egyptian Ministry of Health.

the Sudan and Ethiopia as *Bulinus (Physopsis) globosus* Morelet, and those from Somalia as *Bulinus (Physopsis) abyssinicus* Bourguignat.

Blair (personal communication) classified certain samples from all three countries as *Bulinus (Physopsis) nasutus*; in addition, he considered one sample from Ethiopia to be " intermediate between *nasutus* and *africanus*, closer to *africanus* " and another from Somalia to be *Bulinus africanus*.

TABLE XXV. LAND SNAILS FROM ETHIOPIA, SOMALIA, AND YEMEN

Locality and serial number	Species
Ethiopia	
48. Nakamti, Wallaga Province	*Cerastus*, near to *rüppelianus* Kobelt *Zonitarion*, probably *rüppelianus* Pfeiffer
Somalia	
37. Genale	*Lejeania* sp. (*Helicidae*)
Yemen	
22. Asfaya village, Wadi Dhahr, near San'a	*Lejeania* sp. *Zonitarion*, probably *rüppelianus* Pfeiffer
25. 'Useifira es Sufla, near Ta'iz	*Zonitarion*, probably *rüppelianus* Pfeiffer

The *Bulinus abyssinicus* snails from Somalia are obviously the vectors of bilharziasis haematobia there. No positive data exist for those from the other territories. As pointed out by Archibald,[7] the *Bulinus (Physopsis)* of southern Sudan do not occur in an area of endemicity for bilharziasis haematobia. This, however, is not the case for the snails found near the outlet of Lake Tana and in the Blue Nile, for although infections with *S. haematobium* were not detected in that particular environment during the survey, the subgenus most probably occurs in other parts of the Tana basin, which lies in an area of reported endemicity. A study of the respective roles of the two subgenera in this region would be of great interest.

While in the Gezira, the author learnt that Dr E. Schwarz, of the US Naval Medical School, Bethesda, Md, USA, has diagnosed *Bulinus (Physopsis) africanus* among snails collected from the Gezira canals, which represents their only record of occurrence there. Although the species does exist in the upper reaches of the Blue Nile, it does not seem to be established in the Gezira irrigation scheme or anywhere else in the drainage of the river in the Sudan.

Land Snails

A list of the terrestrial snails obtained during the survey and identified by Mandahl-Barth (personal communication) is given in Table XXV.

GENERAL DISCUSSION

Socio-Economic Aspects of Bilharziasis

The danger of the spread and intensification of bilharziasis in the countries surveyed, in all of which the presence of at least one species of vector snail, actual or potential, has been ascertained, must be emphasized. The rapid increase in world population will necessitate the agricultural exploitation of the tropics in the near future. As irrigation and agriculture develop, the need to conserve water will make an increase in snail habitats inevitable. Labour will be attracted, the population will increase, and at the same time will concentrate around these snail habitats. This will offer optimum conditions for the effective completion of the life-cycle of the parasite and, together with the increase of traffic which will result from economic development, will assuredly spread and intensify the infection. In fact, this development has already been taking place in the Sudan Gezira as regards both types of bilharziasis, and in Somalia as regards bilharziasis haematobia.

Unfortunately this danger has aroused remarkably little interest in most countries up to the present ; this may partly be due to the fact that the policy-making classes are less exposed to the ill-effects of the disease. It must, however, be admitted that bilharziasis is a deceptive disease which does not attack openly, arousing alarm among the population, and inducing the responsible authorities to take counter measures ; it is not usually a killing disease in itself, but causes silent debilitation, so that even the medical authorities are often unaware of the extent of its ravages. It is also well known that the lowered vitality of afflicted persons is not always apparent, because they usually mould their efforts to fit their impaired power, but that they break down under the extra strain entailed by army recruiting, industrialization, or organized intensified agriculture.

The losses due to bilharziasis in terms of money may be divided into two categories :

(1) the cost of antibilharziasis treatment and anti-snail campaigns;

(2) the economic losses caused by the disease and its complications.

The routine course of treatment with antimony lasts about three weeks, during which time the patient should not perform any appreciable manual labour. Thus the per capita cost of one treatment is equivalent to 21 days of work and it is a well-known fact that often the treatment has to be repeated. To this should be added the direct cost of these treatments to the health authorities, and also the cost of the treatment of bilharzial complications. The heavy cost of present anti-snail measures is too well known to elicit comment.

It is difficult to assess the loss in working days due to the disease and its complications, but there is no doubt that it reaches a high figure. Equally difficult to assess quantitatively is the lowered productivity of the infected individuals ; in Egypt, it has been estimated that the labour output of the country is decreased by 33% as a result of bilharziasis.

Although the disease seldom figures as a direct cause of death, even in intensely endemic areas, bilharziasis patients fall a much easier prey to epidemics and concurrent diseases than uninfected persons; there can be no doubt that bilharziasis has a deleterious effect on the life-span and that this represents a great social waste and economic loss. Prevention of these premature deaths would result in a more favourable age-structure of the population, with a larger part of it in the productive ages, and with all age-groups showing a greater ability and willingness to work. According to Khalil,[50] it has been estimated that bilharziasis was the direct or indirect cause of death in 25% of the post-mortems performed at Kasr-el-Aini Hospital, Cairo, Egypt.

Certain endemo-epidemics of bilharziasis have shown the ravages which this disease can cause. Khalil & Abdel Azim [51] reported an epidemic causing a large number of fatalities in Tanan village, Qalyubiya Province, Egypt, which was ultimately traced to *S. mansoni* infection from a stream passing inside the village and heavily polluted from a mosque latrine; the epidemic ceased after the stream had been deviated. According to Helmy,[47] Watson (personal communication) reported that various villages in the marshy areas of southern Iraq have lost as much as half their population through acute bilharziasis haematobia within a few years.

The effects of even relatively mild bilharziasis haematobia as it prevails in the areas of natural endemicity, which are not generally appreciated in a primitive and underdeveloped society, are apparently very marked when observed in groups on which greater demands are made, as for instance in the Union of South Africa. Kieser,[52] who gained experience in the Transvaal Schools Medical Service, claimed that, with a little attention, infection can be diagnosed from the scholastic performance of a child, and that infected pupils quite commonly fail to qualify as apprentices or for higher studies, usually falling out half-way through their school courses; he even observed brilliant children failing completely after infection and dunces who leapt to the head of their class after treatment.

With regard to man-made bilharziasis resulting from irrigation schemes, its serious effects cannot be denied. In fact, the question arises whether the initial increase in economic wealth, following on agricultural expansion, may not, in the long run, be more than balanced by the deterioration in productivity and health. At least one example is known in Southern Rhodesia, where the Umshandige Irrigation Scheme, installed in 1939 at a cost of three million pounds, had to be abandoned after ten years, the extension of bilharziasis in the area contributing materially to the failure of the project (Wright [102]).

The problem, however, need not continue to be economy versus health, provided that the authorities concerned fully recognize the danger of bilharziasis in carrying out economic development programmes, and that they are prepared to take the proper precautions to forestall and minimize its hazards; for the increased mental and physical vigour will more than repay the expenditure on bilharziasis control and prophylaxis. It is therefore highly desirable that the responsible authorities be brought to realize that it is a sound economic investment to pay for an antibilharziasis campaign.

The solution evidently lies in integrating bilharziasis-control measures with the general economic structure of the country and in devoting a sufficient amount of the profits accruing from irrigation and other economic development programmes to remedying the damage these projects cause to the health of the people, whether these profits be private, or governmental through increased income and other taxes. It should be plainly understood that agricultural development in the tropics and subtropics will have to pay the heavy tribute it owes to the people's health.

At the same time, it is undeniable that no medical and public-health services can be established or maintained unless funds are available. In some of the countries surveyed funds will never be available from internal resources until the standard of living is raised through economic development.

Bilharziasis, unlike malaria, is spreading and since the world has become an increasingly interrelated economic and health unit, this scourge should be fought by international rather than by national planning. The underdeveloped peoples must be helped to become capable of helping themselves; for disease and poverty form a vicious circle, while health and progress advance side by side. Fortunately, the principle that the richer nations should aid the poorer is becoming accepted in the world today.

Possible Control Measures

Since it is proposed to launch internationally-supported antibilharziasis programmes in an increasing number of areas, the following measures are to be recommended:

Circulation of basic information

Population surveys and treatment. In view of the fact that extensive population surveys and mass treatment will have to be carried out in a number of countries by hospitals, dispensaries, private clinics, and other institutions, it is suggested that clear and detailed instructions on proper examination and treatment methods be prepared and circulated; the instructions should include details of the methylene-blue method of preparing urine slides suitable for shipping to a central laboratory developed by Barlow.[12] These theoretical directions should be reinforced by regular practical demonstrations.

Snail surveys and control. Since in a number of regions little is known with regard to the distribution of the vector snails, the preparation and circulation of a guide on their recovery and recognition, and on methods for relaxation and preservation of the soft parts for identification, would fill a definite need.

General environmental prophylaxis

Individual study of the domestic water-supplies and sewage-disposal methods in settlements, and especially in public places such as schools, markets, and mosques, with the object of minimizing water pollution, is very important. This subject is discussed more fully on pages 110-111.

In Moslem communities, special emphasis should be placed on the abolition of mosque ablution basins which may play a role in the transmission of bilharziasis, on the installation of running water, and on the sanitary drainage and maintenance of the mosques.

Health education

At our present stage of knowledge, medical, sanitary, and environmental prophylaxis measures will not be sufficiently effective against the spread of bilharziasis and should be supplemented by health education. This, in conjunction with health legislation, should aim at a gradual change in the habits of the people by making them bilharziasis-conscious. In Moslem countries, it should be specially and persistently impressed upon the people that it is contrary to religious tenets to pollute water and thus cause injury to others.

Much could be achieved by arousing the people to the dangers of the disease, and a serious attempt should be made to bring before them the rudiments of understanding as to the manner in which it is contracted, its serious complications and consequences, and the practical means of prophylaxis. In the long run, only a change in the habits of the people will ensure permanent success and, to this end, health education by all methods and at all levels of the population must be carried out with perseverance.

The author fully agrees with Helmy[47] that health education must be directed first and foremost to those who will, in turn, convey the message to others. Preachers, teachers, health visitors, administrative functionaries, and engineers should receive specially adapted courses. An adequate discussion of the disease ought to be included in the curriculum of all schools and colleges, as well as in army and police camps, and success in passing the examinations of the health curriculum should be made essential for graduation. Health education should be made an essential part of the duties of all public-health and hospital personnel. Refresher courses for practitioners are also necessary.

It is thought that modern visual propaganda would be effective in the areas surveyed. Posters showing the life-cycle of the parasite, and small museums attached to hospitals, schools, and mobile propaganda units, are recommended; the exhibits should include specimens, models, or at least photographs of the following: stones of the bladder, ureter, or kidney; septic infections of these organs; urinary fistulae; cirrhosis of the liver, splenomegaly, ascites, and carcinomata. The showing of *Schistosoma* ova under the microscope, or the projection of moving miracidia and cercariae, is very impressive and highly to be recommended. Lantern slides and short films, with simple commentaries, are suitable for communities where illiteracy prevails. The insertion of film strips about bilharziasis in general entertainment programmes would also be of value.

Particularly effective is auditory propaganda, such as sermons and simple lectures, followed by questions and answers and ending in the distribution of small rewards for the best answers. The radio should also be intensively and continuously used for the spread of information, preferably in the form of simple plays.

It is to be hoped that " fundamental education " will be extended and will play a major role in convincing the people that " health is wealth and happiness ", and in furthering the formation of rural committees from among the inhabitants themselves, in order that they may deal with their bilharziasis problems, not as something imposed upon them from the outside, but as their very own programme. Specialized demonstration material and texts (model speeches, commentaries, courses, etc.) might be produced as a guide to health educators, and translated and adapted to suit the requirements of the particular cultural and linguistic groups concerned.

Health legislation

At first, health education will not be sufficient unless reinforced by health legislation. Slight penalties, judiciously applied, will teach the people that certain things cannot be done with impunity. In fact, the author considers that this constitutes " education through legislation ". Such legislation has been initiated in Egypt and it is believed that it will provide the framework for future effective and integrated control. Some of these legal enactments have been described by Helmy [47] in his report on Syria, to which several full texts are appended. The more important Egyptian health regulations, aiming directly or indirectly at the control of bilharziasis, are summarized and commented upon below.

(1) *A law on compulsory treatment for bilharziasis*, compelling the population to undergo examination and treatment (Law No. 58 of 1941).[a]

[a] Egypte, Ministère de la Justice (1942) *Loi No. 58 de 1941 relative à la lutte contre la bilharziose.* In: *Recueil des lois, décrets et rescrits royaux. Année 1941*, Le Caire, p. 291

Although it may not be possible to carry out such a law to its full extent, it will at least contribute towards making both the population and the practitioners bilharziasis-conscious.

(2) *An order making a certificate of freedom from parasitic diseases and bilharziasis obligatory* for admission to schools and colleges (Ministerial Order of 5 July 1941).[a]

This regulation reaches a not inconsiderable cross-section of the population and also contributes to render them bilharziasis-conscious. It is suggested that this measure be extended to admission to government or other controllable posts, and to the obtaining of trade licences, work permits, etc.

(3) *A law for the promotion of rural sanitation and the protection of villagers against disease* (Law No. 62 of 1947).[b]

This law aims at the gradual establishment of general rural hygiene and includes a number of points that have a direct bearing on bilharziasis.

(4) *A law imposing general sanitary obligations on estate owners,* with regard to water-supplies, disposal of excreta, medical care, etc. (Law No. 118 of 1950).[c]

This could be a most useful law, given adequate personnel for follow-up and surveillance.

(5) *A law regulating the location of irrigation streams and their sanitary maintenance by the owners* (Law No. 29 of 1948).[d]

The diversion, filling in, covering, etc., of streams considered to be public health hazards are made the responsibility of the authorities, while the maintenance of proper flow and weed clearance in distributaries situated on private property are made the responsibility of the beneficiaries. The latter provision aims at the ultimate education of the rural population properly to care for the irrigation and drainage channels, a measure which is also advantageous from the viewpoint of agriculture.

(6) *A decree penalising indiscriminate use and pollution of water* (December 1945).[e]

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[a] This order was issued by the Egyptian Ministry of Education to schools as an internal regulation on the date quoted, and was again affirmed by an internal circular letter, dated 31 July 1945. It was published later in the *Journal officiel du Gouvernement Egyptien,* No. 136 (9 September 1948); the subject-matter of the order constituted item 6 of the conditions for admittance into schools for the school-year 1948-49. Freedom from parasitic diseases has been listed under these conditions published yearly thereafter.

[b] Egypte, Ministère de la Justice (1949) *Loi No. 62 de 1947 relative à la réforme de l'hygiène rurale.* In : *Recueil des lois, décrets et rescrits royaux. Année 1947,* Le Caire, p. 72

[c] Egypte, Ministère de la Justice (1952) *Loi N° 118 de 1950 imposant des services sociaux et hygiéniques à certains propriétaires de terrains agricoles.* In : *Recueil des lois, décrets et rescrits royaux. Année 1950,* Le Caire, p. 187

[d] Egypte, Ministère de la Justice (1950) *Loi N° 29 de 1948 relative à l'extermination des mollusques transmetteurs de la bilharziose.* In : *Recueil des lois, décrets et rescrits royaux. Année 1948,* Le Caire, p. 23

[e] Egypte, Ministère de la Justice (1946) *Décret interdisant la pollution des cours d'eau et des étangs.* In : *Recueil des lois, décrets et rescrits royaux. Année 1945,* Le Caire, p. 322

In the author's opinion this decree requires amendment. Stress should be laid on removing or stopping gross pollution rather than on punishing offenders. The health authorities should therefore be given the right to act on their own initiative and at the offenders' expense. Bathing, playing in the water, washing, and ablutions, should be added to the items prohibited in the above decree; while the building or installation of private and public establishments, including prayer places, on the shores or embankments of streams, should be subject to the holding of a licence; this would compel the licencees to comply with the regulations.

Bilharziasis Control in Irrigation Areas

The Joint OIHP/WHO Study-Group on Bilharziasis in Africa,[99] which met in Cairo in October 1949, recommended that the following administrative safeguards should be taken as precautionary measures against the spread of bilharziasis :

> " Every irrigation scheme should be submitted at the earliest planning stage to the public-health authority for consideration. Approval by the public-health authorities should be a condition of its authorization and financing from public funds. Public-health authorities should be represented on the governing body of any irrigation scheme established or sponsored by governments or international organizations. " (page 15)

If these principles be admitted, the question arises as to what should be recommended by the health authorities. Measures in areas where the introduction of bilharziasis is feared will naturally vary, to some extent, from those in areas where it is already established.

Precautions at the inauguration of new schemes

The inauguration of any new agricultural project lying within, or within reach of, endemic areas, should be linked with the following precautionary measures, as applicable:

Medical precautions should consist in:

(*a*) a door-to-door census of the existing population, followed by medical examination for bilharziasis, and by treatment of all infected persons;
(*b*) corresponding examination and treatment of all immigrant labour;
(*c*) subsequent continued follow-up medical surveys and treatment of both population groups.

Sanitary precautions should include:

(*a*) the housing of the population in compact settlements, situated at least 500 m (550 yards), but preferably 1 km (1100 yards), away from natural or artificial watercourses; conversely, new irrigation and drainage channels should be planned to run the same distance from existing settlements;

(*b*) the provision of a free domestic water-supply; from the viewpoint of bilharziasis control, simple hand pumps are usually sufficient; for example, one for every five houses;

(*c*) the provision of latrines for every house and of freely accessible public latrines, laundries, and baths;

(*d*) the provision of safe swimming-holes to the maximum extent possible (it is impossible to stop the children from bathing).

Environmental prophylaxis in irrigation areas

A number of other measures relative to the sanitary maintenance of the irrigation systems themselves, as well as those relative to health education and legislation, already discussed, will all have to operate simultaneously in order to preserve new irrigation areas and improve conditions in old ones.

Since complete and continuous co-operation between the health and other relevant authorities is essential for proper integral action, the author would like to draw attention to the proposals [10] made by him before the Congress for the Study of the Effect of Irrigation and Drainage on Health and Agriculture which met in Cairo in 1946. To ensure such co-operation, he advocated the setting-up of regional joint committees, composed of officials from the Ministries of Health, Public Works (Irrigation), and Agriculture, to whom all new irrigation projects were to be submitted before execution. Among the functions of these committees would also be individual study of existing conditions, with the object of preventing or minimizing water pollution, and a study of domestic water-supplies and adequate methods of sewage disposal, especially in mosques, schools, markets, and other public places. The recommendations of these committees would be forwarded to a central high committee which would have full authority and sufficient funds to carry them out—a most important point, as the efforts of the regional committees would otherwise come to nothing. Naturally, such an arrangement should be modified to suit different areas.

Sanitation of water channels. Strict attention to the following principles should be enforced, with a view to making the streams as unsuitable as possible for snail life and to minimizing contact with the population:

(1) There should be no blind ends to either irrigation canals or drains.

(2) All disused watercourses, seepage water collections, etc., should be filled in.

(3) Water channels should have proper contours and a gradient sufficient to prevent slow current; for the same reason they should have no

sharp curves. Pot-holes, sudden narrowings, or deep siphoning at bridges, roads, etc., should be avoided.

(4) If, for technical or other reasons, it is not possible to attain a minimum distance of 500 m (550 yards) between villages and streams, the water channels should be covered or piped within that distance.

(5) Covering all watercourses is an ideal to be aimed at, as it would not only minimize contact and pollution but would also make snail life impossible, thereby removing the main link in the perpetuation of the disease. The expense of underground drainage, although initially high, would be covered in a few years by the additional area of land gained (usually 8%-15%) and the more effective drainage and thus larger crops obtained. In one area in Egypt, underground drainage has in one single year resulted in a crop increase that more than repaid its installation expenses. It is believed that the much cheaper cost of maintenance and the removal of obstacles from the way of mechanized agriculture in covered irrigation and drainage, together with the preservation of the health of the population, would not only prove its value but actually finance its own extension.

Snail control measures. Where underground irrigation and drainage have not been installed to eliminate the vectors of the disease definitively, snail-control measures, as recommended by the Joint OIHP/WHO Study-Group on Bilharziasis in Africa,[99] will remain indispensable. This vast subject will not be discussed here, beyond the statement that, to ensure maximum potency, molluscocides should be applied when water temperatures are highest.

Bilharziasis Control Outside Irrigation Areas

In areas of natural endemicity for bilharziasis, a number of the prophylactic measures cited above will equally apply, though usually not with the same degree of urgency. Environmental prophylaxis, however, will differ in detail. In sub-arid regions, characterized by definite, isolated watering-places from which the infection is acquired, it is suggested that those stretches of water lying near villages and most frequented by the population be fenced and provided with hand pumps having floating inlets, so as to avoid both pollution and infection.

Priorities

If for lack of sufficient funds, or personnel, or for other reasons, priority of human treatment has to be considered, then it should undoubtedly be given to children and to adolescent groups. They are the most important source of viable, hatchable, schistosome ova and snail-penetrating miracidia and, because of their habits, are also the main source of infection to snails and thus of the maintenance of the life-cycle of *Schistosoma*. Their tissues have not been irreparably injured and they therefore benefit most from treatment. Lastly, they represent the coming generation and the hope of the community. For the same reasons, priority in snail control should be given to stretches of water frequented by children and adolescents. Cercariae-infested snails are a danger signal, and stretches of water containing them should be dealt with at once. In general, snail control should be continuous and intense in watercourses passing near inhabited places.

Priority should be given to *Biomphalaria* infestation, owing to the much greater ravages of mansoni infection.

It is unnecessary to state that endemic areas, and in particular endemic foci, should receive the foremost consideration with regard to mass treatment of the population, as well as intensity of snail control, health education, and sanitation measures.

Research

Better knowledge and better tools are required to improve control of the disease from its various aspects.

Biological

With regard to the vector snails, further emphasis should be placed on the study of bionomics, ecology, and physiology, as such data might provide valuable clues to snail control. Search for natural enemies—viral, bacterial, fungoid, or others—might prove of value. The time of the day and the seasons of the year in which cercariae are preferentially shed by the various snail hosts of the different territories should be investigated, as this might furnish a clue as to the periods when workers should be advised to pursue, or abstain from, agricultural activities. Research on the factors of immunity to bilharziasis, natural or artificial, may well prove to be the corner-stone in the fight against the disease. The problems of vector-parasite relationships need clarification in many African territories.

Chemical

The author believes that the future of bilharziasis control lies to a great extent in development on chemical lines. There exists a general agreement that it will be essential to evolve drugs that are cheaper, safer, and more effective than those at present known, especially as regards:

(*a*) a drug for the treatment of bilharziasis, to be administered orally, which would be free from the severe nauseating effect of the lucanthones (Miracil group), so that it would be used effectively and willingly by the patients at home;

(*b*) a molluscocide that would not react with the silt and organic matter and could therefore be applied to the intakes of canals by a method of constant feeding. This would minimize labour and expense and leave no intermediate periods when the canals would be positive for snails; sodium pentachlorophenate shows promise in this direction;

(*c*) cercariae-repellents and weed-killers, which are also important.

There is no doubt that a successful attack on bilharziasis can be achieved only by team-work between physician, malacologist, chemist, and engineer.

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RÉSUMÉ

Une enquête sur la répartition de la bilharziose dans le bassin de la Mer Rouge et dans quelques pays du Nord-Est africain a été entreprise sous les auspices de l'OMS. En 1951-52, l'auteur a visité le Somaliland, l'Erythrée, l'Ethiopie, la Somalie, le Soudan et le Yémen, et partiellement la Côte française des Somalis et le Protectorat d'Aden. Il a évalué l'endémicité de la maladie grâce à des examens cliniques, à la recherche des parasites dans les fèces et l'urine, à la récolte et la détermination des mollusques vecteurs. La documentation considérable qu'il a réunie, complétée par l'analyse des travaux publiés antérieurement, constitue une somme des connaissances actuellement disponibles sur la répartition de la bilharziose dans cette partie du monde.

Après avoir exposé en détail pour chaque pays le résultat des recherches effectuées et brossé un tableau de la situation dans les régions qu'il a visitées, l'auteur conclut, en un bref résumé, que la bilharziose paraît n'être pas endémique dans les terres basses et arides du littoral de la Mer Rouge. Elle l'est, en revanche, sous l'une de ses formes ou les deux, à l'intérieur des terres et sur les hauts plateaux des deux côtes. La bilharziose à haematobium est endémique dans les terres basses de la région équatoriale, dans les deux principales vallées de la Somalie du Sud.

Les territoires visités, qui hébergent chacun au moins une espèce de mollusque vecteur, réel ou potentiel, sont menacés d'une extension et d'une aggravation de la bilharziose. Il est de toute importance que l'on ne laisse pas empirer la situation dans les régions où l'incidence est encore faible. Le développement économique des régions considérées aura pour conséquence, selon toute probabilité, une augmentation de l'incidence. L'accroissement rapide de la population du globe va entraîner dans un avenir assez proche l'exploitation agricole des régions tropicales. L'irrigation créera des collections d'eau qui abriteront des mollusques. La population des travailleurs agricoles se concentrera aussi dans les régions irriguées et, le trafic s'intensifiant, les conditions les plus favorables à la persistance et à la dissémination de l'infection se trouveront réunies. Ces prévisions ne sont pas seulement théoriques; elles se sont déjà réalisées en certains points, au Soudan et en Somalie.

Des programmes internationaux de lutte contre la bilharziose vont être entrepris dans le monde, en nombre croissant. Pour en faciliter le succès, diverses mesures doivent être prises, en particulier d'ordre éducatif et législatif.

Toutes les mesures prises par les autorités sanitaires ayant pour but d'empêcher la propagation de la maladie et d'assainir le milieu doivent être soutenues par l'instruction

du public, car, en dernier ressort, seul un changement profond des habitudes de la population peut assurer le succès durable de la lutte. Les personnes occupant des postes de commande et jouissant d'une influence parmi la population devraient recevoir un enseignement adéquat. Des notions sur la bilharziose devraient figurer au programme des écoles et au programme des cours destinés aux fonctionnaires, à l'armée et à la police. Tous les moyens éducatifs susceptibles d'atteindre la population devraient être mis en œuvre.

Mais l'éducation du public doit, à son tour, reposer sur une législation appropriée et d'éventuelles sanctions. La législation égyptienne relative à la bilharziose, dont l'auteur mentionne certains des actes principaux, porte en particulier sur le traitement obligatoire de la maladie, le certificat d'absence de maladies parasitaires — nécessaire à l'admission aux écoles et aux établissements d'enseignement supérieur — la réforme de l'hygiène rurale, l'interdiction de la pollution des cours d'eau et étangs, l'extermination des mollusques.

Des problèmes particuliers de prophylaxie se posent dans les régions irriguées. L'auteur mentionne certaines mesures propres à assurer l'entretien des cours d'eau et la destruction des mollusques. Dans les régions non irriguées, la lutte contre la bilharziose revêt, dans ses détails, des aspects différents. Si l'on ne dispose que de fonds limités pour le traitement humain, la priorité sera donnée aux enfants et aux adolescents; les canaux et les collections d'eau fréquentés par les enfants seront aussi les premiers à être désinfestés. La désinfestation des eaux où vivent des *Biomphalaria* aura également la priorité, en raison de la gravité de l'infection à *S. mansoni.*

Les recherches porteront sur l'étude, toujours plus poussée, de la biologie des mollusques vecteurs, la mise au point de médicaments moins coûteux et plus efficaces que ceux dont on dispose actuellement, de molluscocides qui ne se combinent pas avec les substances organiques et la vase, d'herbicides, et de substances répulsives pour les cercaires.

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