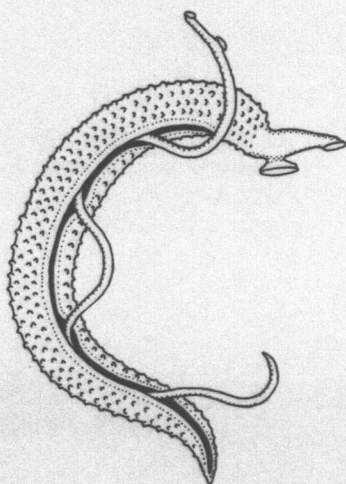
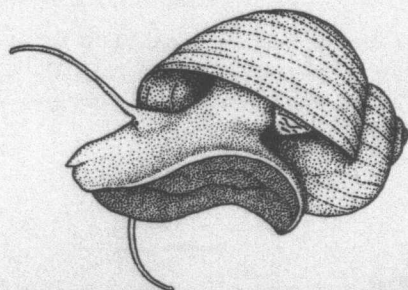


# SCHISTOSOMIASIS and SNAIL HOSTS in JORDAN

A Manual for Diagnosis, Treatment  
and Prevention

John B. Burch and John I. Bruce



# WALKERANA

No. 11

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P.O. Box 2701  
Ann Arbor, Michigan 48106

1990



W A L K E R A N A

Transactions of the POETS Society

Vol. 4

No. 11

# SCHISTOSOMIASIS

and

## SNAIL HOSTS in JORDAN

### A Manual for Diagnosis, Treatment and Prevention

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1990



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## PREFACE

This book was originally produced as part of a joint venture between the project's principle scientists from the United States and from Jordan. The joint project as presented for American funding was devised and written by us (Burch and Bruce) at the request of the American Embassy (Amman) and the Jordanian Ministry of Health. The project was eventually funded by the United States Agency for International Development as a contract to the University of Jordan, with a subcontract to the University of Lowell and a sub-subcontract from the University of Lowell to the University of Michigan. At best, this chain of responsibility and authority proved cumbersome and it was fraught with unnecessary, sometimes contrived problems, continuing obstacles and unrealistic expectations, none of our making on this side of the Atlantic, but seemingly originating from the country for which the project was aimed at helping. Further, a change of American bureaucrats in Jordan before the project was completed seemed to add even more obstacles.

In spite of these problems and with considerable perseverance on our part, this handbook was produced.

An Arabic language version of the manual was also produced in the U.S.A. as part of the project, but due to the problems mentioned above, the Arabic version was not published, unfortunately.

Associated with (or as a direct result of) the difficulties alluded to above, the original edition of this manual received extremely limited distribution. Because of its limited distribution, *Walkerana* is herewith reproducing the manual to make it available to a wider audience, especially to scientists and health workers in the country for which it was intended, and in neighboring regions of the Near East.

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The various sections of this handbook were authored as follows: Schistosomiasis in Jordan [Bruce, Saliba and Rida]; The Schistosome Parasite [Bruce]; Snails and Disease Transmission [Burch]; Freshwater



Snail Fauna of Jordan [Burch and Amr]; Snail Intermediate Hosts of Human Schistosomes in the Near East and Africa [Rudolph and Burch]; Snail Intermediate Hosts of Human and Veterinary Parasites other than Schistosomes in Jordan [Saliba]; Ecology of Freshwater Snails in Jordan [Mallett and Amr]; Snail Control (Chemical and Environmental) [Bruce]; Snail Control (Biological) [Rudolph and Bailey]; Health Education [Burch]; The National Schistosomiasis Control Program in Jordan [Rida and Bruce]. Appendices: Schistosomiasis [Bruce]; Snail Identification (General) [Burch]; Snail Identification (Snail Intermediate Hosts of Human Schistosomes in the Near East) [Rudolph and Burch]; Snail Surveys [Bruce]; Distribution of Freshwater Snails in Jordan [Burch and Amr]; Freshwater Habitats in Jordan [Burch, Amr and Mallett]; Parasitological and Medical Terms [Bruce]; Malacological Terms [Burch]; Ecological Terms [Mallett and Burch]; Parasitological References [Bruce]; Malacological References [Burch]; Ecological References [Mallett]. (Authors alone are responsible for statements in their sections.)

## FORWARD

The materials in this manual are intended to provide malacological and parasitological information and methodology for effectively dealing with human schistosomiasis, not only in the Hashemite Kingdom of Jordan, but also in other countries of the region.

The schistosomiasis laboratory and field survey procedures, as well as ecological field techniques, were devised or adapted by personnel of the Center for Tropical Diseases, University of Lowell, in both Lowell and in projects of the Center in various geographic areas endemic for schistosomiasis and other snail-mediated diseases.

The malacological aspects of this project were under the supervision of personnel of the Mollusk Division, Museum of Zoology, University of Michigan. The actual field surveys in Jordan were carried out by the University of Jordan, mainly by Zuhair Amr, and his diligence in performing the tasks entrusted to him are herewith noted.

In preparing this manual, an attempt was made to provide for Jordan detailed taxonomic, distributional and ecological data on freshwater snails, and parasitological and clinical information on human schistosomes and schistosomiasis. We have also attempted to provide as a backdrop for Jordan an overall framework of schistosomiasis and snail host distribution in Africa and the Near East. Therefore, schistosomiasis and its snail mediators are discussed in a broader view than just in relation to the small country of Jordan.

Throughout the text, we have used the term "Near East" to mean the countries of the eastern Mediterranean, Iraq, and the Arabian Peninsula. We have avoided using the indefinite and unofficial term "Middle East," which refers to an extensive region comprising the countries of southwest Asia (including Iran, Afghanistan, Pakistan, India and Burma) and northeastern Africa.

With further reference to geographical terms it should be mentioned that in providing distributional data for the parasites and snail hosts, we have used the term "Palestine" for the land bordering Jordan to the west, now normally called Israel. However, due to politically imposed constraints, no references to the State of Israel could be made in the original printing of this manual. We had to replace "Israel" with "Palestine" in the manuscript. So, snail distributions cited in the text often refer to "Palestine," but more correctly they should refer to Israel.

## ACKNOWLEDGEMENTS

Grateful acknowledgement is made to the following scientists for reviewing the text and providing helpful comments: Dr. Harold L. Asch (Roswell Park Memorial Institute, New York State Department of Health, Buffalo), Dr. Allen W. Cheever (National Institutes of Health, United States Department of Health and Human Services, Bethesda), Prof. Mahmoud A. El-Banhawy (Faculty of Science, Ain Shams University, Cairo), Prof. Maria Amélia A. Grácio (Instituto de Higiene e Medicina Tropical, Universidade Nova de Lisboa, Lisbon), Dr. Noshay S. Mansour (United States Naval Medical Research Unit No. 3, Cairo), Prof. M. F. A. Saoud (Faculty of Science, University of Qatar, Doha, Qatar), Prof. Shi-Kuei Wu (University of Colorado Museum, Boulder) and Prof. Fouad Yousif (Theodor Bilharz Institute, Enbaba, Cairo).

We thank the following individuals for assistance in preparing the Handbook: Cindy Greska, Younghun Jung and Janet White-Rudolph.

We express our appreciation to the Ministry of Health of Jordan and the United States Agency for International Development for their generous support of the activities which culminated in the production of this handbook.

*Corrigenda*

Page 25, second paragraph, line 2, 10th word, for "in" read "is"

Page 73, second paragraph, line 3: for "bieng" read "being."

Page 167, first paragraph, line 2: for "small" read "snail."



## Part I. SCHISTOSOMIASIS



## Part I. SCHISTOSOMIASIS

Human schistosomiasis is a debilitating disease caused by members of the digenetic trematode worm genus *Schistosoma*, which use certain freshwater snails as intermediate hosts. Schistosomiasis is a major malady of man, afflicting an estimated 200 million people in many tropical and subtropical regions of the world. To its victims, schistosomiasis inflicts hardship, suffering, economic disadvantage, and, in many cases, eventual death. Once the transmission cycle of the disease has been established in a country or region, it has proven very costly and especially difficult or impossible to contain or eliminate.

In the Near East\*, there are two types of human schistosomiasis, schistosomiasis haematobium and schistosomiasis mansoni. Schistosomiasis haematobium (also called urinary or vesical schistosomiasis) is the more prevalent of the two types of disease, and transmission of the causative parasite to man is known to occur in most of the Near Eastern countries. Schistosomiasis mansoni (also called intestinal schistosomiasis) occurs in the Near Eastern countries of Saudi Arabia, Oman, North Yemen and South Yemen, and nearby Egypt. Transmission of either type of human schistosomiasis is not known to have occurred in Jordan during historical times, but recent events indicate that the disease could likely become established in the country, and because of that threat this handbook on schistosomiasis and malacology has been prepared.

\*The countries constituting the Near East are Turkey (which does not have human schistosomiasis), Iraq, Syria, Lebanon, Palestine, Jordan, and the countries of the Arabian Peninsula. Schistosomiasis also occurs in nearby Egypt and Iran.

## 1. Schistosomiasis in Jordan

### Infected People

Transmission of schistosomiasis has never been known to occur in Jordan. The infection has been diagnosed, however, in Jordanian citizens, but, in all except one doubtful case, exposure to the schistosome parasite was shown to have occurred outside of Jordan, usually in one of the countries with which Jordan shares common borders. The doubtful exception was discovered in 1975, when a case of urinary schistosomiasis, which appeared to have been contracted in Jordan, was diagnosed by the Royal Jordanian Medical Services. Interviews with the patient seemed to indicate that he had never travelled outside of Jordan, although there might be some doubt about that. As a follow-up to this questionable case, a survey of 3,000 Jordanian citizens was conducted while they were outpatients at government clinics in the Jordan Valley. Urine examinations of these outpatients for *Schistosoma haematobium* eggs showed no evidence of infection.

At the present time, transmission of schistosomiasis still does not appear to be occurring in Jordan\*, in spite of the large numbers of foreign nationals that come to Jordan each year from countries that have areas endemic for the disease. Many of these visitors come for the purpose of employment; others come as tourists. Some of the visitors have been confirmed to be infected with schistosomiasis by the Jordanian Ministry of Health, which examines foreigners that come to Jordan for employment. During the period of June through December 1977, urine examinations of 17,000 foreign workers revealed that 8% (mainly Egyptians, and Pakistanis and Indians from Africa or the Near East) had urinary schistosomiasis. During the period from March 1979 to April 1982, 42,600 urine samples from migrant workers were examined for eggs of *Schistosoma haematobium*, of which 10,011 (23.5%) were found to contain the eggs. The Ministry of Health administers treatment to certain migrant workers found infected with urinary schistosomiasis, especially laborers who will work on farms and other agricultural facilities in the Jordan Valley (that is, those that have high probability of contact with natural fresh water). Undoubtedly, some of the migrant workers will also be suffering from schistosomiasis mansoni (intestinal

\*Since this was written, several cases of *Schistosoma haematobium* infection endogenous to Jordan have been reported. — ED.

schistosomiasis, caused by *Schistosoma mansoni*), since that disease is also present in many of the countries where the workers live.

### Snail Intermediate Hosts

A major factor in the absence of schistosomiasis in Jordan has been the lack of the snail intermediate hosts in the country. During earlier surveys for the snail intermediate hosts by various investigators, no snail species which serve as intermediate hosts for human schistosomes had been found. However, in 1975, and after diagnosis of the questionable indigenous Jordanian case of urinary schistosomiasis mentioned above, the waters of 64 localities in the Jordan Valley were surveyed for snails. The snail vector for *Schistosoma haematobium*, which causes urinary schistosomiasis in the Near East, *Bulinus truncatus*, was discovered in one of the water bodies examined. This site was a cemented reservoir in the Muthalath Al-Masri area approximately 13 km south of Deir Alla village, which receives its water periodically from the East Ghor Canal. No other *Bulinus* snail focus was discovered in the Jordan Valley during the 1975 survey or during the subsequent limited surveys conducted in 1977 and 1978. However, in 1979, a second focus for *Bulinus truncatus* was discovered in an ancient Roman pool approximately 1.5 km west of the town of Jerash and 48 km from Amman. Water from this pool is delivered via two cement canals to Jerash Valley for use in irrigation at farms in the greater Jerash area. During the winter season, water from the Jerash pool overflows into the Wadi of Jerash, then flows to the Zarka River and the King Talal Dam impoundment, and subsequently reaches the Jordan Valley.

In 1980, following construction of the King Talal Dam and the subsequent filling of its basin with water, *Bulinus truncatus*, the snail intermediate host for *Schistosoma haematobium* in the Near East and adjacent regions, was discovered in large numbers throughout the King Talal Dam basin and in drainage and seepage areas adjacent to the dam itself.

Following the discovery of bulinine snails in the King Talal Dam, *Bulinus truncatus* was discovered at various sites in the Jordan Valley. These sites were Shaikh Hussain, Zour Al-Hammam, Tal-Salman, Ain Taha, Mahrab Abu Ahmad and Zour Al-Mojajaja. Further discoveries of *Bulinus* snails were made in the Zarka River area. *Bulinus truncatus* shells were also found at Ain Abu Fareed and Al-Manchia (Haloka Spring), thus indicating that live *Bulinus* snails once were present at these localities.

Each year in Jordan, thousands of the agricultural workers who enter the country are from regions where schistosomiasis is endemic. Many of these workers have both urinary and intestinal schistosomiasis, thus constituting an infection pool to act as a source for the introduction of schistosome eggs into Jordanian waters. In addition, there are also many vacationers who enter Jordan from countries where schistosomiasis is endemic and, thus, may also pose a potential public health threat to the country.

One of the criteria used by the government of Jordan to assess the potential for schistosomiasis to become established in the country has been to determine the susceptibility of the various introduced *Bulinus* snail populations to infections with schistosome strains obtained from migrant workers, as well as from a schistosome strain maintained for years in a laboratory animal, the hamster. These studies showed that all the *Bulinus truncatus* populations as yet discovered in Jordan could be infected with *Schistosoma haematobium* from Egypt. This demonstrated that the presence of the susceptible *Bulinus* snail populations, together with the yearly entrance into Jordan of thousands of infected migrant workers, poses a potential for the establishment of schistosomiasis transmission in Jordan, a country which in recent times has been free from that disease.

### Ecology

Due to the increased development of new water resources in Jordan, significant changes are occurring in the natural hydrography of the country. The ancient schemes for bringing water from the mountains to the Jordan Valley, and hence to the barren Dead Sea, have been replaced by conduits such as the East Ghor Canal. The development of extensive secondary and tertiary canals to distribute water for irrigation to extensive farming areas in the Jordan Valley, as well as the King Talal Dam and fish-farming operations, provides good habitats for the snail intermediate hosts of schistosomiasis to become established. The results of physical and chemical analyses of the water from various types of waterbodies indicate that many of these localities have habitats that potentially are capable of sustaining snail intermediate hosts of human schistosomes. It also should be noted that these areas that have potential for *Bulinus* snail infestation are among those waterbodies that are most frequented by the foreign migrant agricultural workers.

## 2. The Schistosome Parasite

Transmission of human schistosomiasis has not been discovered thus far in Jordan,\* but, nevertheless, two species of human schistosome have been found infecting migrant workers in the country. These parasites are *Schistosoma haematobium*, which cause urinary schistosomiasis, and *Schistosoma mansoni*, which cause intestinal schistosomiasis.

### The Life Cycle of the Schistosome Parasites

People may become infected when they come in contact with water containing infective stages of the schistosome parasite. The larvae which are infective to humans are called cercariae (see Fig. 1). These are microscopic forms, measuring about 0.2 mm in length, which swim freely

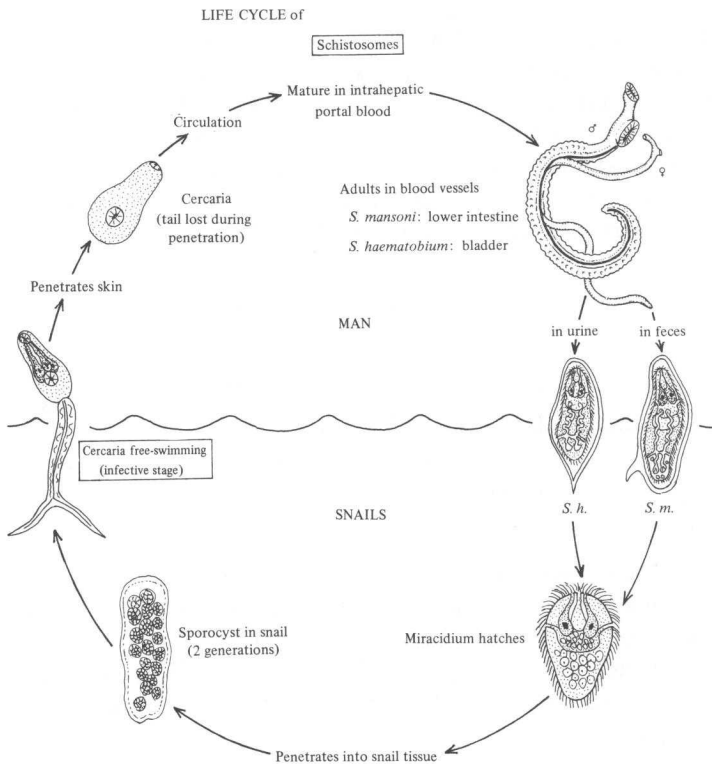


FIG. 1. Life cycle of *Schistosoma haematobium* and *Schistosoma mansoni*.

\*See footnote, page 4.

in water, and are able to seek out a person and penetrate the skin (skin cuts are not necessary for penetration). Cercariae are able to survive freely in water for approximately 24 to 72 hours, after which time they die if they have not found a human or other suitable mammalian host to penetrate. Cercariae have long-forked tails to assist them in swimming. When the cercariae enter a person's skin, they shed their tails.

After penetrating the skin, the cercariae develop into another larval stage, the schistosomula, enter the venous circulation or the lymphatic vessels and pass through the right heart to the lungs and finally reach the liver, where they mature to adult worms. This maturation takes about 50 days for *Schistosoma mansoni* and about 80 days for *Schistosoma haematobium*. Each adult worm is either a male or a female (they are not hermaphrodites as are most trematode parasites). The longer and more slender female lies in the gynecophoric canal (see Fig. 1) of the broader and more muscular male. Adults of both sexes have oral and ventral suckers by which they attach to the inner walls of the blood vessels of the intestine or bladder. Adult worms may live up to 20 years or longer in the body. After the worms mature, they mate in the liver and the worm pairs pass down the venous blood vessels from the liver to live in veins of the bladder (*Schistosoma haematobium*) or of the intestine (*Schistosoma mansoni*), where egg laying occurs. Aberrant localizations may also be found in various other parts of the body. Each female *Schistosoma haematobium* worm produces about 150 eggs each day; female *Schistosoma mansoni* produce 300 or more eggs each day. The egg of each species has its own characteristic appearance (Table 1).

TABLE 1. Characteristics of human schistosome eggs.

Species	Length (microns)	Breadth (microns)	Diagnostic features
<i>S. haematobium</i>	112-170, av. 150	40-70, av. 60	Terminal spine
<i>S. mansoni</i>	114-175, av. 150	45-70, av. 60	Lateral spine

*Schistosoma haematobium* eggs have a terminal spine while *Schistosoma mansoni* eggs have a lateral spine (see Fig. 1). The eggs pass through the walls of the bladder or intestine to enter the urine or feces. The eggs contain a fully-developed small larval form, called a miracidium. They pass from the body at the time of urination or defecation and hatch upon entering the water.



The ciliated miracidia which hatch from the schistosome egg shells can live in the water for periods of 8 to 12 hours or more, after which they die if they have not found a proper snail host. *Schistosoma haematobium* miracidia search out and specifically infect freshwater snails of the genus *Bulinus*, and *Schistosoma mansoni* miracidia specifically infect snails of the genus *Biomphalaria*. The miracidium penetrates the snail tissue, changes into a mother sporocyst, which in turn gives rise to daughter sporocysts, which then migrate to the digestive gland and sometimes the reproductive gland of the snail. Here further multiplication occurs by asexual reproduction, and a new type of larvae, called cercariae (the stage infective to man) are produced. The time involved for the miracidium to develop into a mother and then a daughter sporocyst and finally to produce the infective cercariae is approximately four weeks at 26-28°C. When mature, the cercariae emerge from the snail and enter the surrounding water to begin the cycle once again. One miracidium can produce several thousand cercariae, but each cercaria can produce only one adult worm.

The factors necessary for completion of the schistosome life cycle are the presence of (1) humans, (2) the proper snail intermediate host, and (3) fresh water. Therefore, control of schistosomiasis is directed toward treatment of infected persons to prevent passage of schistosome eggs into fresh waters, destruction of the snail intermediate host, and preventing human contact with infested water.

### The Life Cycle of the Snail Intermediate Hosts

Certain species of freshwater snails are necessary for the establishment of the schistosome life cycle. For *Schistosoma haematobium* in the Near East and Africa, these snails must be members of the genus *Bulinus*. In North Africa and Southwest Asia, *Bulinus truncatus* is the snail intermediate host (see Fig. 1). This snail species has been found recently in Jordan. For *Schistosoma mansoni*, snails of the genus *Biomphalaria* serve as the intermediate host (see Fig. 1). As yet, snails of this genus have not been found in Jordan.

*Bulinus truncatus* snails are found in a variety of waterbodies in Jordan, such as dams and associated drainage systems, semipermanent and permanent ponds, and tertiary irrigation canals, swamps, rivers and their drainage systems, streams and springs. The temperature of waterbodies where *Bulinus truncatus* snails are found in Jordan varies from 12°C to 28°C. The snails deposit their eggs on various hard surfaces in

these waters; the eggs hatch within one to two weeks, depending on prevailing conditions, including food supply, temperatures, etc. The snails reach maturity within one to four months and live for 12 months or longer.

During the dry season, when the water of many habitats dries up, some snails may burrow into the mud or sand of the habitat, and thus a few usually can survive from one season to another. Since the snails have a very high fecundity rate, they can rapidly repopulate their habitats once fresh waters are again abundant.

### Description of the Disease, Diagnosis and Treatment

#### A. Schistosomiasis Haematobium (Urinary Schistosomiasis)

##### 1. Life Cycle

*Schistosoma haematobium* inhabits veins of the vesical and pelvic plexus. A visual and prominent characteristic of the disease caused by infection with *Schistosoma haematobium* is the presence of blood in the urine, known as haematuria.

The adult female schistosome deposits its eggs in the walls of the bladder, ureters or urethra. Many eggs pass slowly through these walls and are carried from the body in urine, which may show haematuria. However, some eggs may reach the rectum and then they are carried from the body in feces. Once the eggs enter the water, they hatch immediately, releasing ciliated larvae, miracidia, which only can develop further in certain species of the snail genus *Bulinus*. If they do not find the proper species of snail, the miracidia will die. Once in the snail, the larvae develop as described on page 9. When the resulting cercariae are released from the snail, the cercariae swim in the water and if they come in contact with a human they penetrate the skin. In the human, the schistosomulae migrate to the liver and develop into adult schistosome worms, which migrate by way of the inferior haemorrhoidal veins to the veins of the vesical and pelvic plexuses.

##### 2. Clinical Symptoms

A dermatitis (swimmer's itch), caused by penetration of cercariae into the skin, may start on the day of infection and continue for two to three days. The dermatitis reaction is not as severe from *Schistosoma*

*haematobium* or *Schistosoma mansoni* cercarial penetration as it is from penetration by avian or nonhuman mammalian schistosome species. For the nonhuman species, the cercariae penetrate the human skin, but die because humans are not their specific host. The enhanced dermatitis results from allergic reactions to these dead nonhuman schistosome larvae.

The incubation period in man for *Schistosoma haematobium* is approximately 10 to 12 weeks. Early symptoms of the disease occur at four to six weeks after exposure to cercariae; this is a state of toxemia or anaphylaxis. Irregular fever, malaise, pain and urticaria of the generalized type occurs. An eosinophilia (15-30%) is also observed, which gradually decreases later.

Approximately three to six months following infection, localized symptoms occur due to the presence of schistosome eggs. Urination occurs more frequently, with hematuria and pain on urination. Much of the severe disease is related to obstruction of the upper urinary tract, with resultant dilation of the ureters and kidney. This process is usually without symptoms until advanced and irreversible disease is present. Obstruction may occur relatively early in the disease in young individuals. At this stage, it is generally reversible with treatment to kill the parasites and may even return toward normal without treatment, perhaps because the infection is dying out spontaneously. Clinical symptoms vary from individual to individual.

### 3. Pathology

Eggs which do not pass through the bladder into the urine are retained in the tissues, where they cause a severe inflammatory reaction. In the early stages, this causes cystitis, giving rise to the hematuria and discomfort described above. Somewhat later, the inflammatory reactions produce disease either because of their size or because of the fibrosis which usually follows. The most common severe disease is related to obstruction of the upper urinary tract so that urine flow is hindered and pressure builds in the ureters and in the kidneys, where the functioning renal tissue is compressed by the expansion of the renal pelvis and calyces. The lesions causing this obstruction may be in the ureters or in the bladder. Recent inflammatory lesions are often reversible, while fibrotic older lesions generally do not change with time or chemotherapeutic treatment. Eggs may also commonly find their way into the lungs, where they rarely cause pulmonary arteritis with pulmonary hypertension and cor pulmonale. Some *Schistosoma haematobium* worms live in the portal circulation, where they lay eggs which

reach the liver and colon, inciting local reactions but rarely causing significant disease. In severe infections, other lesions in the bladder include benign polyps, ulcers and bladder cancers. Eggs may be present in other pelvic organs such as the prostate gland and seminal vesicles in males, and the vagina, uterus, fallopian tubes and ovaries in females.

#### 4. Diagnosis

##### a. Microscopic Examination of Urine

The World Health Organization recommends a standard procedure for use in examination and diagnosis of urine from suspected cases of urinary schistosomiasis (see Appendix A, p. 107). Examination of a urine specimen passed at midday provides the best chance of finding the terminal-spined egg. Specimens collected at early morning do not contain as many eggs as does urine passed at midday or later. Small drops of urine taken near the end of urination or from sediment of centrifuged samples are placed on a microscope slide and examined under low-power of the microscope for presence of eggs. The eggs can be seen easily since they are quite large (112 to 170  $\mu$  in length by 40 to 73  $\mu$  in width) and are many times the length of a red blood cell (which measures about 7.2  $\mu$  in length). When heavy or moderate infections are present, many red blood cells will always be present in the urine specimen. After successful treatment, red blood cells will disappear from the urine.

##### b. Rectal Mucosal Biopsy

A proctoscope with a good light is used to take a small piece of tissue from the rectal mucosa. The biopsy specimen is then pressed between microscope slides and examined, fresh and unstained. Eggs may be found by this diagnostic procedure, especially when they are absent in a urine specimen. [Since *Schistosoma haematobium* eggs are rarely found in the intestine (or in fecal samples), this is not a common method for diagnosis of urinary schistosomiasis.]

##### c. Cystoscopy

Use of a cystoscope, a special instrument with a light at the end, to examine the interior of the bladder may allow one to see visual evidence of urinary schistosomiasis lesions on the inner lining of the bladder.

However, this procedure is used for diagnosis only when cystoscopy is being done for other purposes.

#### d. Serology

The immune system of man responds to infection by the schistosomes which are pathogenic to man (for example, *Schistosoma mansoni* and *Schistosoma haematobium*) by forming antibodies. The immune reactions produced are used in immunodiagnostic methods to diagnose schistosomiasis. In many instances, when microscopic diagnosis fails to demonstrate schistosome eggs in feces, urine or biopsy material, the clinical-based suspicion of schistosomiasis may be supported by a positive serum reaction obtained after the employment of one of several serological procedures. In addition to such serological methods as the Complement Fixation Test (CFT), Indirect Hemagglutination (IHA), Indirect Immunofluorescence (IIF) and various other precipitation and radioimmunological techniques, the intradermal reaction (skin test) using antigens prepared from adult worms can be used for epidemiological and other purposes.

##### 1) Intradermal (Skin) Test

The schistosomiasis skin test is used for diagnosis of infection because of its relatively high sensitivity (93-100%) and simplicity in performance, together with low cost and results which can be quickly available. This test is used in preliminary screenings before more specific diagnostic procedures are employed (see Appendix B, p. 111). [The intradermal test may still be positive after the patient has been cured of the schistosome infection.]

#### e. Hatching of Schistosome Eggs

See Appendix E, (p. 121) for details of this technique.

### 5. Treatment

Two preferred drugs currently are readily available for use in the treatment of urinary schistosomiasis: a) Biltricide, and b) Metrifonate. Although only these two drugs will be discussed, it should be realized that other antischistosomal agents have been used in the recent past,

and that several additional drugs are anticipated to become available in the near future.

a. Biltricide (Praziquantel)

Trade name: Biltricide

2-cyclohexylcarbonyl-1,1,2,6,7,11b-hexahydro-4H-pyrazino-(2;1-a) isoquinoline-4-one; generic name: Praziquantel.

**Efficacy:** Six months after therapy, follow-up investigations in Africa under field conditions have yielded parasitological cures of 88-100% for *Schistosoma haematobium* and 75-80% for *Schistosoma mansoni*.

**Tolerance:** Biltricide is very well tolerated and as a rule unwanted side effects are mild, transient and do not require treatment.

**Side Effects:** Occasional abdominal discomfort with or without nausea, headache, dizziness, rise in temperature and, rarely, itching (urticaria).

**Precautions:** As a general rule, Biltricide should not be taken during the first three months of pregnancy, although animal experiments do not point to any harmful effects on either a pregnant woman or the unborn child. Lactating women may be treated provided the baby is not nursed on the day of treatment and during the subsequent 72 hours. In areas where cysticercosis is known to exist, special care must be taken since cerebral cysticercosis may be aggravated by Biltricide and requires hospital-based treatment by a specialist.

**Indications:** Infections due to all species of schistosomes (for example, *Schistosoma haematobium*, *Schistosoma mansoni*, *Schistosoma intercalatum*, *Schistosoma japonicum*), liver flukes (e.g., *Clonorchis sinensis*, *Opisthorchis viverrini*) and lung flukes (e.g., *Paragonimus westermani* and other species) pathogenic to man.

**Contraindications:** None known thus far.

**Tablet:** One lacquered tablet of Biltricide contains 600 mg of drug.

**Dosage:** The following dosages are recommended for the treatment of individual patients infected by *Schistosoma haematobium*: 1 x 40 mg Biltricide per kg bodyweight as a **one-day treatment**. The number of tablets needed can be calculated from the following table.

TABLE 2. Dosages of Biltricide (Praziquantel) for various bodyweights.

Bodyweight in kg	No. of tablets equivalent to 1 x 20 mg/kg	Bodyweight in kg	No. of tablets equivalent to 1 x 25 mg/kg
20-25/26	3/4	22-26	1
26/27-33	1	27-33	1-1/4
34-41	1-1/3	34-38	1-1/2
42-48	1-1/2	39-44	1-3/4
49-56	1-3/4	45-50	2
57-63	2	51-56	2-1/4
64-70	2-1/4	57-62	2-1/2
71-78	2-1/2	63-68	2-3/4
79-86	2-3/4	69-75	3

The tablets are best taken unchewed with some liquid, preferably after a meal. In case of repeated intake on the same day, the interval between the individual doses should not be less than 4 and not more than 6 hours.

#### b. Metrifonate (Trichlorophon)

Trade name: Bilarcil; also known as Néguvon and Dipterex

Dimethyl 2,2,3-trichloro-1 hydroxethyl phosphonate ( $C_4 H_8 Cl_3 O_4 P$ ) is an organophosphorous compound.

**Efficacy:** Three to four months after therapy, follow-up investigations have yielded parasitological cure of over 90%.

**Tolerance:** Metrifonate is tolerated very well. Gastric and hepatic tolerance are good. **Contraindications** are not known.

**Precautions:** The simultaneous exposure of patients under Metrifonate treatment to substances inhibiting cholinesterase may cause side effects. Such exposure occurs in patients that handle or contact some compounds which are used, for example, in crop protection for erradicating insects or antihelminthic treatment of animals. The simultaneous use of DDT does not impair Metrifonate therapy. Should serious side effects occur due to uncontrolled intake, the immediate administration of Atropine sulphate is recommended (for example, SC injection of 1 mg once or several times).

**Composition:** Each tablet contains 100 mg Metrifonate.

**Dosage Scheme:** Single dose of one tablet per 10 kg bodyweight (Table 3). This dose is repeated every two weeks to maximum of three doses. The tablets are swallowed whole with some water. It is recommended not to exceed the number of tablets stated.

TABLE 3. Dosages of Metrifonate (Trichlorophon) for various bodyweights.

Bodyweight		Tablet per Single Dose
kg.	lbs.	
10	22	1
15	33	1-1/2
20	44	2
25	55	2-1/2
30	66	3
35	77	3-1/2
40	88	4
45	99	4-1/2
50	110	5
55	121	5-1/2
60	132	6
65	143	6-1/2
70	154	7
75	165	7-1/2
80	176	8
85	187	8-1/2
90	198	9
95	209	9-1/2
100	220	10

## B. Schistosomiasis Mansoni (Intestinal Schistosomiasis)

### 1. Life Cycle

*Schistosoma mansoni* inhabits the inferior mesenteric veins of the large intestine. The adult female schistosome deposits her eggs in the small venules of the submucosal layers of the large intestine. The eggs,



which have a lateral spine, penetrate the intestinal mucosa and reach the lumen of the intestine and are voided in feces. Other eggs remain in intestinal tissues or are carried by the portal blood to the liver, while others reach the lung and other organs of the body by way of the hemorrhoidal plexus and anastomotic veins. The eggs hatch immediately upon contact with fresh water, releasing the ciliated miracidia, which must find and penetrate certain species of the snail genus *Biomphalaria* in order to develop further. Once in the snail, the larvae develop as described on page 9. When cercariae are released from the snail and come into contact with a person in the water, they penetrate the skin, become schistosomula and migrate to the liver, develop into mature schistosomes, and then migrate to the mesenteric veins of the large intestine.

## 2. Clinical Symptoms

A dermatitis also occurs from *Schistosoma mansoni* cercarial penetration, as described previously for invasion of the skin by *Schistosoma haematobium* cercariae.

The incubation period for *Schistosoma mansoni* in man is approximately five to six weeks. The toxemic acute phase of the disease usually is more severe than that from urinary schistosomiasis. Fever, nausea, vomiting, diarrhea, abdominal pain and tenderness, a dry cough with dyspnea and urticaria may occur. Eosinophilia of 30% is common, with a total white cell count of 15,000 or more. Acute toxemic schistosomiasis is almost never seen in patients living since birth in endemic areas, but would be expected to occur in areas in which infection has been recently introduced.

Following the acute phase, patients infected with *Schistosoma mansoni* have few symptoms. It is well to remember that residents of established endemic foci rarely have acute disease either, so the infection is often without symptoms until advanced disease is present. This usually takes the form of hepatosplenic disease, characterized by enlargement of the liver and spleen and, because of obstruction of the flow of blood through the liver, high pressure within the portal system (that is, in the veins leading from the intestine to the liver). Among the veins that dilate to allow blood to bypass the liver are those in the esophagus. Rupture of these veins produces massive hemorrhage into the esophagus and stomach, the most common cause of death in these patients. About 10-20% of patients with hepatosplenic disease also develop schistosomal cor pulmonale, described above for *Schistosoma haematobium* infections, or glomerulonephritis, the latter as a result of the body's immune

reaction. Many eggs are present in the intestines, but the relation of this to intestinal symptoms is not clear in most cases. However, some cases develop numerous polyps and severe diarrhea, which may be life threatening. In other severe cases, large inflammatory masses in the intestines or their linings may mimic malignant tumors of the abdomen. Depending on the worm load and other factors, the effects from infection with *Schistosoma mansoni* vary from person to person. The majority of infected individuals suffer no severe effects.

### 3. Pathology

*Schistosoma mansoni* eggs are deposited mainly in the capillaries and venules of the large intestine and the lower portion of the small intestine. Many eggs do not penetrate the intestinal wall and are then carried to the liver by the venous blood. In the liver, they are trapped and eventually provoke granulomas and fibrosis, leading to portal hypertension, esophageal varices, splenomegaly and ascites in the most severe cases. Anastomoses occur between the mesenteric-portal veins and the vena cava become enlarged permitting eggs, and sometimes worm, to be carried to the lungs, causing granulomatous arteritis and obstruction of the pulmonary circulation. This leads to cor pulmonale and right ventricular failure in 10-20% of the cases with severe liver disease. Worms rarely migrate to the spinal cord and deposit eggs which produce granulomas resulting in transverse myelitis and paralysis.

### 4. Diagnosis

#### a. Microscopic Examination of Feces

1) The World Health Organization recommends a standard procedure for use in examination of feces from suspected cases of intestinal schistosomiasis (see Appendix C, p. 115).

2) The direct-smear method is the simplest to use, but is very insensitive. Approximately 2 mg of feces are placed on a microscope slide and mixed with water or physiological saline (0.9% NaCl) and examined immediately under a microscope. Egg counts are reported as eggs-per-smear and the appropriate calculations can be made to determine eggs-per-gram of feces.

3) The AMS III concentration method is a very accurate method for use in the laboratory (see Appendix D, p. 119).

NOTE: Negative stool results should be followed up by at least two more examinations in order to achieve a greater than 90% probability of finding true positive patients.

#### b. Rectal Biopsy

Rectal biopsy is a very useful technique for use in diagnosing *Schistosoma mansoni* infections when fecal examination is negative. The procedure is carried out using a proctoscope with a good light to remove a small piece of tissue from the rectal mucosa. The fresh specimen is crushed between glass slides and examined unstained using a compound microscope. Eggs may be found by use of this diagnostic procedure, especially when they are absent in fecal specimens in persons suspected of having chronic or light schistosomiasis.

#### c. Hatching of Schistosome Eggs

See Appendix E (p. 121) for details of this technique.

#### d. Serology

The same serological tests as described for use in *Schistosoma haematobium* infection can be employed for diagnosing *Schistosoma mansoni* infections, but using *Schistosoma mansoni* antigens (see Appendix B, p. 111).

### 5. Treatment

*Schistosoma mansoni* infections are more difficult to cure than *Schistosoma haematobium*. Two drugs are currently preferred: a) Biltricide and b) Oxamniquine.

#### a. Biltricide (Praziquantel)

See the section on treatment of *Schistosoma haematobium* infection (p. 13) for information concerning trade name, side effects, precautions, indications, contraindications, composition and table showing number of tablets needed for administration at certain bodyweights.

**Dosage:** Based on results obtained thus far, the following dosages are recommended for the treatment of individual patients infected by

*Schistosoma mansoni*: 1 x 40 mg or 2 x 20 mg Biltricide per kg body-weight as a one-day treatment.

b. Oxamniquine

Trade name: Vansil (brand of Oxamniquine)

1,2,3,4-tetrahydro-2-[[[(1-methylethyl) amino] methyl]-7-nitro-6-quinoline-methanol is a tetrahydroquinoline derivative for the oral treatment of *Schistosoma mansoni* infections.

**Tolerance:** Oxamniquine is generally well tolerated, especially if given after food.

**Contraindications:** At present, there are no known contraindications to the administration of Oxamniquine.

**Side Effects:** Transitory dizziness/drowsiness occurred in approximately one-third of the patients assessed. Other effects observed to a lesser degree are headache, nausea, vomiting, abdominal pain and anorexia. Urticaria has also been reported. In rare instances, epileptiform convulsions have been observed.

**Warning:** In rare instances, epileptiform convulsions have been observed within the first few hours after ingestion of Oxamniquine. When a convulsion occurred, it was usually in a patient with a previous history of convulsions. Oxamniquine should be used with care in such individuals, and they should remain under medical supervision with facilities available to treat a convulsion should it occur.

**Precaution:** Oxamniquine has been shown to have an embryocidal effect in rabbits and mice when given in doses 10 times the human dose. There are no adequate and well-controlled studies in pregnant women. Oxamniquine should be used during pregnancy only if the potential benefit justifies the potential risk to the fetus. Treatment of schistosomiasis can almost always be deferred until after the completion of pregnancy.

**Nursing Mothers:** It is not known whether this drug is excreted in human milk. Because many drugs are excreted in human milk, caution should be exercised when Oxamniquine is administered to a nursing mother.

**Efficacy:** Cure rates of 88% to 95% have been claimed from use of this drug to treat patients in Brazil infected with the Western Hemisphere

strain of *Schistosoma mansoni*. Less efficient cure rates have been found in Africa.

**Indications:** Oxamniquine is indicated for all stages of *Schistosoma mansoni* infection, including the acute phase and the chronic phase with hepatosplenic involvement.

**Composition:** One capsule of Vansil contains 250 mg of drug.

**Dosages and Administration:** The recommended dosage is 12-15 mg per kg of body weight given as a single oral dose. The recommended capsule dosage according to body weight is as follows.

TABLE 4. Dosages of Oxamniquine for various bodyweights.

Bodyweight in kg	No. of 250 mg Capsules
30-40	2
41-60	3
61-80	4
81-100	5

**Children:** The recommended dosage for children under 50 kg in weight is 20 mg/kg of body weight given in two divided doses of 10 mg/kg in one day with an interval of two to eight hours between doses.



## Part II. MALACOLOGY





## Part II. MALACOLOGY

### 3. Snails and Disease Transmission

Digenetic trematode worms, which include the parasites causing schistosomiasis (pp. 7-9) and fascioliasis (pp. 78-79), must infect, alternately, at least two different animals in order to survive and reproduce to continue their existence. For most trematode species, one of these animals must be a snail and the other animal must be a vertebrate. For schistosome trematodes, the vertebrate animal must be a mammal, and for some schistosomes the mammalian host must be a human. For such species, the larval forms of the schistosome parasite must first infect and develop in a snail, and then the advanced larval stage must exit the snail and infect and develop to an adult worm in a human (see Fig. 1, p. 7). The adult worms in the human host produce eggs which exit the human and release a larval form which infects the snail. This, then, is the life cycle of the schistosome parasite. It alternates between the human (definitive) host and the snail (intermediate) host, and in the process extracts nourishment from both hosts, and causes pathological damage to both hosts.

The larvae of the various trematode parasite species do not develop in just any snail. In fact, each parasite species is very specific in regard to the one or several snail species in which it can develop. The three schistosome species that infect humans in the Near East, the Mediterranean region and Africa are able to develop in snail species of only two genera, *Bulinus* and *Biomphalaria*. *Schistosoma haematobium*, the parasite causing urinary schistosomiasis, infects *Bulinus* snails, and *Schistosoma mansoni*, which causes intestinal schistosomiasis, infects *Biomphalaria* snails. A third schistosome species infecting humans in central Africa is *Schistosoma intercalatum*, which also infects *Bulinus* snails. The latter schistosome parasite has not been found in the Near East or in Africa north of the Sahara.

Other trematode diseases are mediated by yet other snails. For example, trematodes causing fascioliasis in man and his domestic animals have snails of the genus *Lymnaea* as their intermediate hosts (see pp. 78-79).

Because of the special role played by freshwater snails in the mediation of trematode diseases, special attention must be given to the study

of snails in any program designed to eliminate the human diseases related to the snails. It is necessary to know the snails' distinguishing characteristics, distributions, ecology, habitats, interrelationships with other snails and invertebrate and vertebrate animals, etc.

In the section of this handbook which follows, descriptions are given of all the freshwater snail species that occur in Jordan. Descriptions are given also of the various hierarchical groups (subclasses, orders, families, genera, etc.) in which the snail species are classified, and for each snail species is given the general geographic distribution, and distribution and habitats in Jordan. At the end of the section is an "Identification Key" (pp. 52-58) to aid in the specific determination of any species that might be found during snail surveys in the country. These text materials are supplemented by a section on "Snail Identification" in the Appendices (pp. 123-138) and by a "Glossary" for malacological terms (pp. 192-206).

#### 4. Freshwater Snail Fauna of Jordan

The freshwater snail fauna of Jordan is not a rich one, comprising only some 17 species. However, the geographic area is relatively small and fresh water in much of the country is not plentiful. A large part of Jordan is desert. The snails occurring in Jordan are a mixture of faunal elements of the Mediterranean, Palearctic (Euro-Asian) and Afrotropical ("Ethiopian") regions, and the few species which can be found in Jordan belong to disparate and taxonomically diverse snail groups. Because of the mountainous terrain, there are many springs in the country, and it is not surprising that most of the Jordanian aquatic snail species prefer or can tolerate spring habitats. Nearly all of Jordan's freshwater snail species are restricted to permanent water bodies. Probably few are capable of withstanding desiccation of their habitats. Also, frequent fluctuations in water levels, as well as habitat modifications, are likely to have an adverse effect on most of the species. However, one species that exhibits some tolerance in regard to both of these factors in other regions of its distribution is the medically important species *Bulinus truncatus*.

##### Subclass Prosobranchia

The Prosobranchia are one of the three great groups (subclasses) of snails, the other two being the Pulmonata (see p. 41) and the solely marine Opisthobranchia. These three subclasses have been named in reference to the position or character of the respiratory apparatus. In the Prosobranchia, the respiratory organ (the gill), is located in front of the heart; in the Opisthobranchia, it is behind the heart. The Pulmonata have replaced the gill with a vascular lung. In addition to these and other anatomical differences, the prosobranch snails can be distinguished from pulmonate snails by the presence of a cover, the operculum, used to close the shell aperture after the snails are withdrawn into their shells (see Figs. 88, 89; p. 174, 175). Pulmonate snails lack such an operculum.

The prosobranchs account for nearly half of all the snail species. They occur in most habitats available to mollusks, and have many species living in fresh waters throughout the world. Prosobranch snails are divided into four groups or orders, based on characteristics of their anatomy. Two of these groups, the Neritacea and the Mesogastropoda (p. 30), are represented in Near Eastern fresh waters.

### Order Neritacea

The Neritacea are separated from the entirely marine order Archaeogastropoda, where they were formerly placed, because of several basic differences in their anatomy. In the evolution of the Neritacea, the post-torsional left kidney has been retained, while the right kidney has been lost. In the Archaeogastropoda, nearly the reverse has occurred: the right kidney has been retained, while the left kidney has been greatly reduced. Also, males in the Neritacea possess a penis and the females have oviducal glands to provide nutriment to their eggs. These two modifications allow internal fertilization, permitting neritaceans to live in freshwater and some species even to live on land. In the Archaeogastropoda, on the other hand, males do not have a penis, and females generally lack accessory glands in their reproductive tracts. Accordingly, archaeogastropods can live only in the sea.

### Family NERITIDAE

The Neritidae are largely marine and are well represented throughout the world, especially in tropical and subtropical regions. There has been a tendency for various lineages of neritids to invade estuarine habitats, and freshwater and terrestrial ones as well. Two freshwater species are found in Jordan, *Theodoxus jordani* and *Theodoxus macrii*.

The shells of neritids are usually subglobose or hemisphaerical, have few whorls, very reduced spires and very large body whorls. These characteristics, together with the generally thickened shell with heavily calloused and expanded parietal apertural margin, produce a rather typical shape, referred to as *neritiform*. The shell is generally smooth, often polished, and its columellar margin is toothed. The operculum is paucispiral (see Fig. 90,b; p. 175), calcified, and contains a pair of projections, or apophyses ("rib" and "peg"), on the inner columellar side (Fig. 2,a).

### Genus *Theodoxus* Montfort

This is a genus of western Europe, Egypt and the Near East. The shells of its species are small (less than 10 mm in height or length), more or less globular in shape, have a smooth surface, and they frequently show highly variable color patterns within populations. The opercula of species in Egypt, Jordan and the Arabian Peninsula have a small but clearly developed peg.

*Theodoxus jordani* (Sowerby)

Shell (Fig. 2,a) medium in size, up to 15 mm in length, with about 4 whorls, zebrated (generally), or with white spots on a dark background, or uniform black or dark purple to yellow in color. Zebrated shells have red or brown to deep purple or black zig-zag stripes on a white or yellow background. The shell is imperforate, and has a wide, flat, white parietal callus. The spire is very short, the body whorl large, elongate, and usually has a broad, shallow constriction. The aperture is D-shaped, and is tightly closed by an operculum of the same shape.

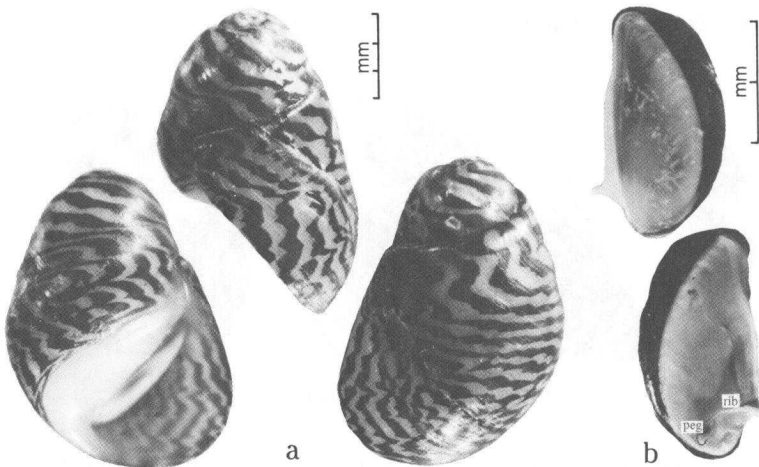


FIG. 2. a, *Theodoxus jordani*, shell; b, operculum of *Theodoxus macrii*.

**General Distribution:** Widely distributed throughout the Near East, but absent from the Sinai and Arabian peninsulas.

**Distribution in Jordan** (Map 2, p. 158): Found at various sites along and near the Yarmouk and Jordan rivers and the East Ghor Canal, and at Azraq. Not common.

**Habitats:** Found in a variety of habitats, most often in springs and large streams, but also in the East Jordan Canal and a secondary canal at Abu Sedo, and in the swamp in southern Azraq.

*Theodoxus macrii* 'Recluz' Sowerby

Shell (Fig. 3) with the same general characteristics as *Theodoxus jordani*, but somewhat smaller, uniformly black or dark purple in color, and without a constriction in the body whorl. The shell is ovate in apertural or top view, and hemispherical in side view. Operculum (Fig. 2,b) as in *Theodoxus jordani*.

Dagan (1971) contended that *Theodoxus jordani* and *Theodoxus macrii* are one and the same species, a conclusion based on details of the opercular apophyses and the central teeth of the radula. However, since the shell types of these two nominal species are readily distinguishable in our Jordanian collections, we prefer to recognize both species until more conclusive evidence is presented regarding their taxonomy.



FIG. 3. Shell of *Theodoxus macrii*.

**General Distribution:** Asia Minor, Jordan, Syria, Palestine and Iraq.

**Distribution in Jordan** (Map 3, p. 158): Common in northern Jordan, especially in the Yarmouk area and the Jordan River valley. Near the northern Dead Sea, *Theodoxus macrii* was found at Othaymat, Quas-miya, Barakat and Halwah springs near Swaimenh. Further south, near the Dead Sea, it was found at Ben Hammadn and Sekeen springs. It was also found at La'aban, near Tafilah Spring and Azraq Druz, and in the springs and streams in the mountainous part of the country.

**Habitats:** Most commonly found in springs, but *Theodoxus macrii* is also associated with other kinds of habitats: spring pools, streams, rivers, swamps, a pond, a primary canal and a dam.

#### Order Mesogastropoda

The largest and most diverse group of prosobranch snails is the

Mesogastropoda. These snails differ from the Neritacea by having only one auricle (rather than two) in the heart, a single muscle (rather than two) attaching the shell to the animal, narrow radulae that have lost the rhipidoglossan character (including the reduction of the large number of marginal teeth to only two on each side), etc. The Mesogastropoda differ from the evolutionarily more advanced order Neogastropoda (an almost totally marine group) by seemingly minor differences, such as possessing unipectinate (rather than bipectinate) osphradia, less concentrated nervous systems, shells which usually lack siphonal canals, and different types of radulae.

#### Family VALVATIDAE

This family is a small one, containing only about 20 extant species inhabiting the Northern Hemisphere. All species except one (*Borysthenia naticina* (Menke) of eastern Europe) belong to the single genus *Valvata*. The animals of *Valvata* are oviparous hermaphrodites. (Hermaphroditism, which is characteristic of the Pulmonata, is rare among prosobranch snails.) The animals have a single bipectinate gill on the left side, and a peculiar pallial tentacle on the right side of the mantle cavity (see Fig. 26,b; p. 54). The shells of nearly all species of *Valvata* are comparatively small, and their nuclear whorls possess both transverse and spiral sculpture. The operculum is corneous, thin and multispiral (Fig. 90,a; p. 175).

#### Genus *Valvata* Müller

Species of this genus are found in North America, Eurasia and the Near East, and northeast Africa. Their shells are small, depressed and umbilicate. Other distinguishing characteristics are mentioned above, under the family.

#### *Valvata saulcyi* Bourguignat

The adult shell (Fig. 4) is about 4 mm in diameter, has 3 1/2 to 4 whorls, is depressed helicoid, rather widely umbilicate, translucent, pale to tannish-horn, with well-developed transverse striae and faint spiral striae. The sutures are moderately deep. The round aperture is closed by a round, thin, corneous, multispiral operculum.



FIG. 4. Shell of *Valvata saulcyi*. f = foot; o = operculum; p = penis; S = shell.

There is some doubt as to whether *Valvata nilotica* Jickeli of Egypt, Sudan and Ethiopia is specifically distinct from *Valvata saulcyi*.

**General Distribution:** Syria, Jordan, Palestine and southern Sinai.

**Distribution (Map 4, p. 159) and habitat in Jordan:** Found only at Al-Hashra swamps near the Yarmouk River.

#### Family BITHYNIIDAE

The Bithyniidae are found throughout Europe and Asia, and in Africa, Indonesia, the Philippines and Australia. They have often been included in the family Hydrobiidae, but bithyniids have many characters that argue against that, such as their size (adult shells of many species are more than 10 mm long), calcareous operculum with paucispiral nucleus and concentric edges, nuchal lobes of the head-foot, relatively long, flexible and acute tentacles, yellow and orange skin pigment granules, etc.

#### Genus *Bithynia* Leach (in Abel)

The genus *Bithynia* is common in Europe and Asia, and its distribution extends into the Arabian Peninsula. Its species have small to medium-sized, dextral shells with opercula fitting close to the apertural lip. The operculum is calcareous, thickened, and, except for the small spiral nucleus, is concentric (see Fig. 90,d; p. 175). A number of "species" have been named for the Near East, but most of these names are synonyms.



*Bithynia philalensis* (Conrad)

The shell (Fig. 5) is horn or tannish-horn in color, moderately glossy, rather solid, translucent, smooth except for sculpture of fine growth lines, imperforate, perforate or rimately perforate, with impressed sutures and up to 5 whorls. Shells of the largest specimens reach nearly 10 mm in length. The spire height varies from being less than the height of the shell aperture to being noticeably greater than that of the aperture. The aperture is entire, and is ovate in shape. The calcareous, concentric operculum has a small spiral nucleus,  $1/6$  to  $1/5$  the width of the operculum. The operculum barely fits the shell aperture.

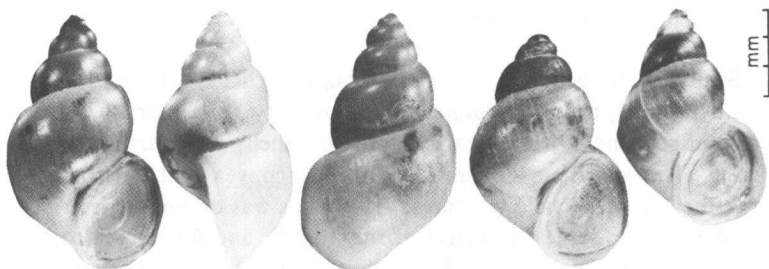


FIG. 5. Shell of *Bithynia philalensis*.

The head-foot of the animal is black or gray; the mantle is covered with melanin pigment, interspersed with circular-shaped (generally) areas devoid of pigment.

**General Distribution:** Jordan, Palestine, Lebanon and Syria.

**Distribution (Map 4, p. 159) and habitats in Jordan:** Found at Azraq Druze and southern Azraq, and in northern Jordan at Shaik Hassain Spring, Jordan River at Shaik Hassain Bridge, Wadi Khaled, and at Al-Tarfeh and Al-Hashra swamps near the Yarmouk River.

Family HYDROBIIDAE

The Hydrobiidae are one of the most common and widely distributed snail families, occurring in temperate, subtropical and tropical regions throughout much of the world. The family is a large one, containing more than 100 genera. Most hydrobiid species live in fresh water, although some are associated with brackish water. Shells of hydrobiids

are small (many are minute), generally elongate, dextral, nearly always drab and unicolored, and generally have relatively few whorls. The shells of most species are plain, but some have prominent surface sculpture. The shell aperture is closed by an operculum, which is corneous (not calcareous) and is generally paucispiral.

Because of the similarity of the shells of many species occurring in different genera and subfamilies, reliance must be placed on anatomical characters, especially those of the reproductive systems, in making identifications and for assigning species to genera and genera to subfamilies. Since the anatomical characters of several of the hydrobiid species in Jordan are not known, their taxonomic placement in this manual is presumptive. Further studies may change their systematic status.

#### Genus *Semisalsa* Radoman

Snails of this genus have conical, elongated shells, with moderately pointed apices, are imperforate, smooth or very faintly striate, and in younger specimens, and often in adults, the shells are glossy and transparent. The whorls are moderately to slightly convex, and are separated by either deep or shallow sutures. The genus was originally described for species from brackish waters of the Adriatic and Aegean sea coasts. The two species occurring in Jordan fresh waters have been assigned to *Semisalsa* by Schütt (1983) on anatomical grounds. In previous reports, these species were placed in the genus *Hydrobia*, or "*Paludestrina*" (which is a synonym of *Hydrobia*).

#### *Semisalsa longiscata* Bourguignat

The shell (Fig. 6) is small, 4 to 6 mm in length, narrowly to elongately conic, basically imperforate, with up to 6 1/2 whorls, tan to

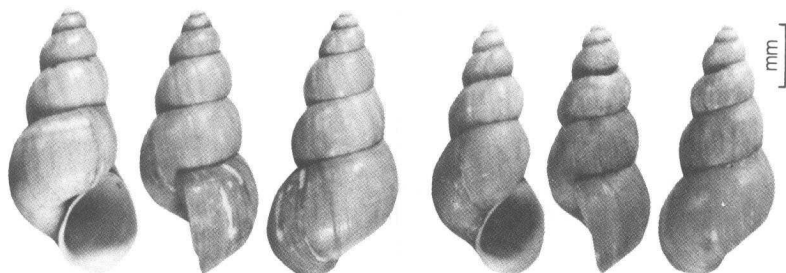


FIG. 6. Shell of *Semisalsa longiscata*.

light horn in color, sometimes with one or more transverse brown bands on the body whorl. The shell is translucent in juveniles, opaque in adults, and smooth or sculptured with fine transverse lines. The sutures separating the whorls are noticeably impressed, which is the feature that most readily separates this species from *Semisalsa contempta*.

**General Distribution:** Named originally from Saida, Lebanon, *Semisalsa longiscata* also occurs in Jordan, Syria, Palestine and Turkey.

**Distribution (Map 5, p. 159) and habitats in Jordan:** Found only at Azraq, in the springs and associated swamp: Al-Azraq, Asad Spring and southern Azraq. In previous reports, this species has been called "*Hydrobia lactea*", a name which may be a synonym.

*Semisalsa contempta* Dautzenberg

Shell (Fig. 7) small to minute (2 to 3 1/2 mm in length), narrowly to elongately conic, imperforate, with 5 to 5 1/2 whorls, light horn in color, generally translucent, smooth or with many fine growth lines, sometimes with hardly visible spiral striae. The sutures separating the whorls are shallow, which is the feature that most easily separates this species from *Semisalsa longiscata*.

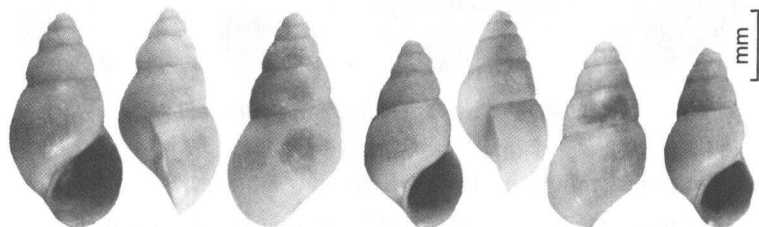


FIG. 7. Shell of *Semisalsa contempta*.

**General Distribution:** Known from Jordan, Syria and Lebanon.

**Distribution in Jordan (Map 5, p. 159):** Found in a number of localities in northeastern Jordan, at Beer Al-Azraq near Swaimeh, and in Debaa and Rehab springs around Tafilah.

**Habitats:** Found mostly in springs, but also in streams (Al-Maleh Wadi, Okla Wadi and Al-Kafer Wadi) and in a swamp at Bast Al-Feleh Mashareh.

Genus *Pseudamnicola* Paulucci

This taxon was named originally in the 19th century for the purpose of distinguishing European snails with shells similar to the North American genus *Amnicola*. Recently, characters of the soft anatomy have been included in the generic description of *Pseudamnicola*. The shells range in shape from strongly depressed to subovately or subglobose conic.

*Pseudamnicola gaillardotii* Bourguignat

Shell (Fig. 8) small,  $2\frac{1}{2}$  to  $3\frac{1}{2}$  mm in length, subovately to subglobose conic, with about  $4\frac{1}{2}$  to  $5\frac{1}{2}$  whorls. The shell is narrowly umbilicate to perforate, glassy and transparent to translucent horn. The aperture is entire. Although the length of the spire is variable, its length is generally about the same as or a little more than that of the aperture.

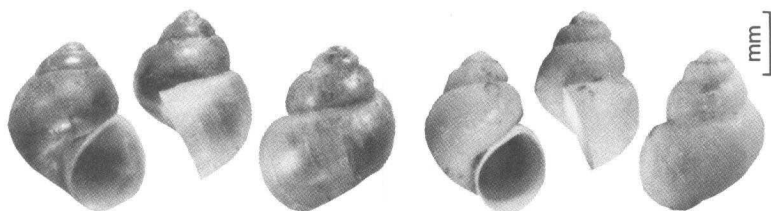


FIG. 8. Shell of *Pseudamnicola gaillardotii*.

**General Distribution:** Jordan, Syria and Lebanon.

**Distribution (Map 6, p. 160) and habitats in Jordan:** Found in northern Jordan in scattered and varied habitats: springs (Barakat Spring, Ein Al-Amayreh at Saham-Irbid, Al-Ma'alaka Springs at Ruwaihah, and Ein Om Ershid at Irbid), a mineral-water spring (Zarat Spring) and swamps (Beer Al-Azraq near Swaimah, Bast Al-Faras, and Basat Al-Faras at Kebed-Al-Karama).

*Pseudamnicola solitaria* Tchernov

Shell (Fig. 9) minute, 1 to  $1\frac{1}{2}$  mm in length, with about 4 whorls, globose, glassy, nearly transparent, narrowly umbilicate, with entire aperture.

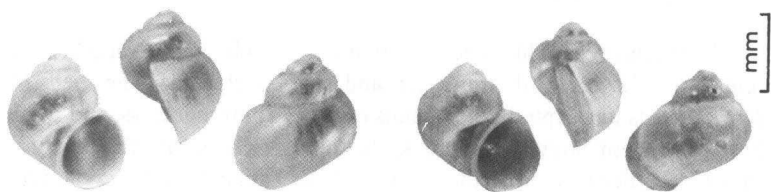


FIG. 9. Shell of *Pseudamnicola solitaria*.

**General Distribution:** Jordan and Palestine.

**Distribution (Map 6, p. 160) and habitats in Jordan:** Found at two localities: in a swamp at Beer Al-Azraq near Swaimeh, and in a stream at Al-Kafer Wadi.

*Pseudamnicola* (?) sp.

Shell (Fig. 10) subovately to ovately conic, small (from about 3 mm to nearly 5 mm in length), imperforate, with 5 to 5  $\frac{3}{4}$  whorls, tannish-horn in color, opaque, sculptured with growth lines and faint spiral striae.

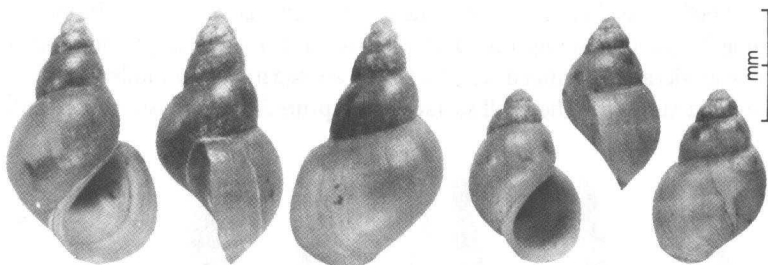


FIG. 10. Shell of *Pseudamnicola* sp.

**General Distribution:** Known only from Jordan.

**Distribution (Map 6, p. 160) and habitats in Jordan:** Found in the Yarmouk River at Zour Al-Breej, the river in Wadi Khaled at Irbid, in a pond at Azraq Druz, in a swamp at Zour Al-Nees near the Yarmouk River, and in a spring at Ein Om Ershid at Irbid.

## Family THIARIDAE

The shells of the Thiaridae are commonly darkly colored and heavily sculptured, having both transverse and spiral sculpture. The shells of some species have spiral color bands or other color markings, and some have prominent nodules or spines. In the older literature the family is called Melaniidae, based on the genus *Melania* Lamarck 1799, a synonym of *Thiara* Röding 1798. Reproduction in thiarids is parthenogenetic, occurring without males. The brood pouch of the females is not uterine, but adventitious (subhaemocoelic) in the neck region, with an opening on the right side of the snails' necks. An easily recognizable characteristic of the family distinguishing them from other freshwater prosobranch snails is the fleshy finger-like processes on the mantle edge.

Genus *Melanoides* Olivier

The species of this genus have medium to large, sturdy shells, which usually have long and narrow spires, and have both transverse and spiral sculpture. The first few whorls (i.e., those at the tip of the spire) are often broken or eroded away. The aperture is relatively small.

*Melanoides tuberculata* (Müller)

Shells (Fig. 11) vary in size, the larger ones reaching nearly 50 mm in length and containing up to 15 whorls. The shell is imperforate, and has moderately rounded whorls, which are separated by moderately impressed sutures. The shell surface is sculptured with transverse ribs and

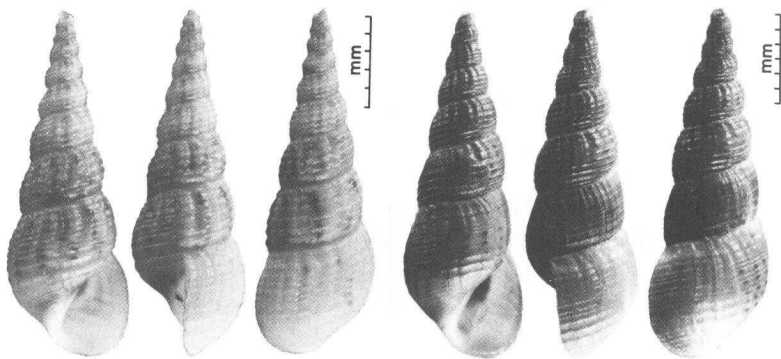


FIG. 11. Shell of *Melanoides tuberculata*.

spiral ridges and grooves (although in some regions of the species' distribution populations occur which contain shells that are almost or completely smooth). The shell is light horn or somewhat darker in color, with reddish-brown color patches. The anterior shell aperture is evenly curved. The posterior aperture is not narrowly constricted, as it is in *Melanopsis praemorsa*.

**General Distribution:** Much of Africa and the eastern Mediterranean countries, including Arabia, some islands in the Indian Ocean, throughout India, Southeast Asia, Malaysia and southern China, north to the Ryukyu Islands of Japan, south and east through many of the Pacific islands to northern Australia and the New Hebrides; introduced into the southeastern United States and into Cuba.

**Distribution in Jordan** (Map 7, p. 160): Found at Azraq Druz, in the Yamouk Valley, and in a number of localities in the Jordan Valley (from Mafadi Spring and Zoor Al-Hamam in the north to Om Hakeem Spring in the south). This species is rather common in Karama and Swaimeh north of the Dead Sea, and at Ghor Al-Mazrah and Ghor Al-Safi at the southern end of the Dead Sea.

**Habitats:** Found in a variety of habitats: springs, streams and swamps, in the Yarmouk River, in secondary canals at Swalha and at Abu Sedo, in a pond at Azraq Druz, in an artesian well at Al-Karama Wells, in spring/pools at Shaik Hussain Spring and Al-Yabis Agricultural Station, and in a dam at Kafreen.

#### Genus *Melanopsis* Férussac

This is a genus of Europe, North Africa, Asia Minor and the Near East. The shells are medium in size (up to about 30 mm in length), elongate, rather thick and solid, imperforate, and, depending on the species, may be smooth or heavily sculptured. The truncate anterior columella (see Fig. 85,c; p. 173) and the sinus on the anterior ("basal") apertural margin are easily recognizable distinguishing characteristics of this genus. Also distinctive is the very narrowly constricted posterior aperture of the shell.

#### *Melanopsis praemorsa* (Linnaeus)

This species, originally named from southern Europe [? Sevilla, Spain], occurs throughout much of the Mediterranean area. In the

eastern Mediterranean region, it occurs on Peloponnesos, Crete, the southern Aegean islands in western Turkey, Transcaucasia, Jordan, Saudi Arabia, Syria, Palestine, Lebanon and Iraq. It has been found at one locality in the Sinai Peninsula, but otherwise it is absent from Egypt. *Melanopsis praemorsa* is a very variable species, to which many scientific names have been employed in the past. This variation may be genetically determined or environmentally produced. Two forms or races are found in Jordan, the smooth *Melanopsis praemorsa buccinoidea* and the ribbed *Melanopsis praemorsa costata*.

*Melanopsis praemorsa buccinoidea* Olivier

This is the smooth form or race of *Melanopsis praemorsa*. The shell (Fig. 12) is of medium size, up to 23 mm or more in length, with about 7 whorls, imperforate, with pointed spire, flattened whorls, lacks sutures with any impression, and is without spiral sculpture. Except for hardly noticeable growth lines, the shell is smooth. The shell color is deep chestnut-brown, often with a lighter area on the body whorl. There is a low, wide callus on the anterior parietal apertural wall.

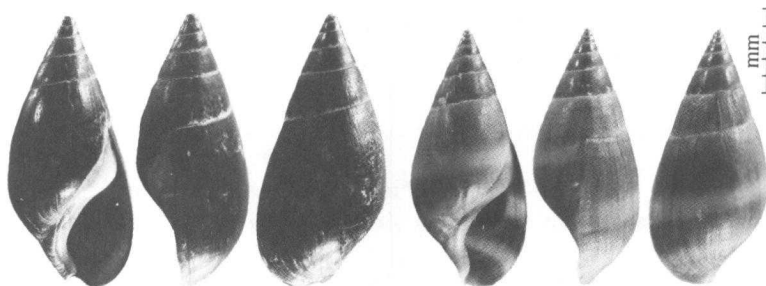


FIG. 12. Shell of *Melanopsis praemorsa buccinoidea*.

**General Distribution:** Jordan, Palestine, Syria, Lebanon and Turkey.

**Distribution in Jordan** (Map 8, p. 161): This form or race was collected at more localities in Jordan than any other snail. It is very common in northern Jordan, and is found at various localities east of the Dead Sea. Other localities include Azraq (Azraq Druz and the swamp at southern Azraq), La'aban Spring near Tafilah, and Ma'an Spring.



**Habitats:** Most commonly found in springs, but this form or race occurs also in streams and rivers, canals and swamps.

*Melanopsis praemorsa costata* (Olivier)

This is the ribbed form or race of *Melanopsis praemorsa*. The shell color is tan to very dark chestnut-brown to nearly black. Tan shells have darker reddish-brown spiral color bands. Other shell characters (Fig. 13) are as in *Melanopsis praemorsa buccinoidea*.

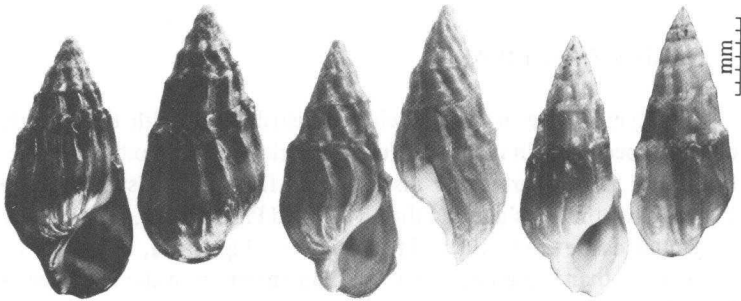


FIG. 13. Shell of *Melanopsis praemorsa costata*.

**General Distribution:** Jordan, Palestine, Syria, Lebanon and Turkey.

**Distribution (Map 9, p. 161) and habitats in Jordan:** Not as common as *Melanopsis praemorsa buccinoidea*, but nevertheless frequently encountered and occurring in all types of freshwater habitats found in Jordan. It was most common in the Jordan and Yarmouk rivers, and in the springs and streams near the two rivers.

#### Subclass Pulmonata

In the Pulmonata, the gill found in the Prosobranchia has been replaced by a vascularized pulmonary cavity (lung) which can breathe either water or air, depending on the habits of the particular species. The great majority of the pulmonate species are land inhabitants, but there are many pulmonate species which also live in fresh waters. Only a few pulmonate snails live in marine environments.

### Order *Limnophila*

The freshwater-dwelling pulmonate snails are placed in the order *Limnophila* (a name which means literally "freshwater-loving"). In contrast to the land-dwelling pulmonate snails, the limnophiles have only one pair of tentacles, at the base of which the eyes are situated (see Fig. 75,a; p. 136). [In terrestrial pulmonate snails, the eyes are situated on the distal tips of the upper pair of tentacles.] The *Limnophila* contains four important freshwater snail families, the *Lymnaeidae*, *Physidae*, *Planorbidae* and *Ancylidae*. Of these, only the *Ancylidae* (a family of freshwater limpets) have not been found in Jordanian fresh waters.

### Family LYMNAEIDAE

The *Lymnaeidae* are world-wide in distribution, with their greatest diversity occurring in northern North America. Their dextral shells (see Fig. 80,b; p. 169) are easily distinguished from the sinistral shells (see Fig. 80,a) of the *Physidae* and the high-spired *Planorbidae*. The tentacles of lymnaeids are broad, flat and triangular (see Figs. 75,a, 89,a; pp. 136, 175) rather than being long, thin and filamentous as in the *Physidae* and *Planorbidae*.

The genus *Lymnaea* has been variously used to include nearly all members of the family *Lymnaeidae* (e.g., see Hubendick, 1951) or only the Holarctic *Lymnaea stagnalis*, its varieties, and several closely related species. In the latter system, the family is considered to contain a number of species groups (genera) equal in rank to the genus *Lymnaea sensu stricto*. A third system, and the one used here, is more or less a compromise between the previous two; it uses *Lymnaea* as a large inclusive genus, but recognizes various subgeneric groups within it. These subgenera (for example, *Radix* and *Fossaria*) correspond to genera in the second system above.

### Genus *Lymnaea* Lamarck

The genus *Lymnaea sensu lato* includes all members of the family that have a coiled shell. As such, the genus is nearly world-wide in distribution. According to the species, this shell may vary in length from only a few mm to more than 40 mm. Only family members with limpet-shaped shells are placed in the second genus, *Lanx*, and these occur only in western North America.

Subgenus *Radix* Montfort

The subgenus *Radix* is the most widely distributed subgenus in the family. Its members have shells with large, often globose, body whorls, which lack spiral striations. The subgenus is a Eurasian-African one, but one species in particular, *Lymnaea (Radix) auricularia*, has been widely distributed by human commerce (its dispersal aided locally, no doubt, by aquatic birds).

*Lymnaea (Radix) natalensis* Krauss

The shell (Fig. 14) is medium in size, 12 to 15 mm in length, thin (but not especially fragile), has a relatively large body whorl and a small and pointed spire, is tannish-brown in color, translucent, perforate, without spiral sculpture, lacks a columellar plait (or has only a slight trace of one), and has a thin and sharp apertural lip. The shell surface is moderately glossy, with distinct (but not prominent growth) lines.

*Lymnaea (Radix) natalensis* belongs to the *Lymnaea (Radix) auricularia* complex of species. It differs from *Lymnaea (Radix) auricularia* s.s. by the lack of a pronounced columellar plait on the shell, and anatomically by the nearly equal lengths of the preputium and penial sheath. *Lymnaea auricularia* usually has a pronounced columellar plait, and in the genital system the penis sheath is shorter than the preputium.

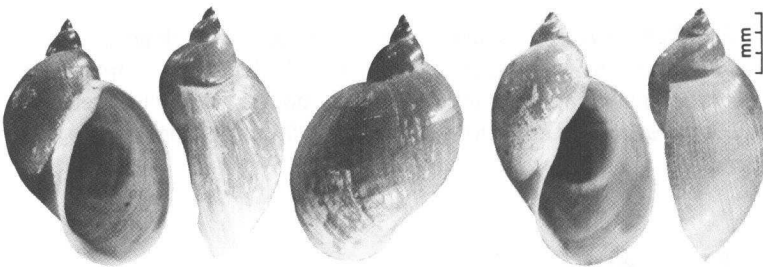


FIG. 14. Shell of *Lymnaea (Radix) natalensis*.

**General Distribution:** All of sub-Saharan Africa, in a number of oases of the Sahara, in the Nile drainage of Egypt, and in Yemen, Oman and Palestine; also found on Cape Verde, and on Madagascar and neighboring islands.

**Distribution in Jordan** (Map 10, p. 162): Found at eight localities near the Yarmouk River in northernmost Jordan, at Taha Spring in the Jordan Valley, and at Azraq (Berjes/Azraq and in the swamp at southern Azraq). In previous reports, this species has been called *Lymnaea auricularia*.

**Habitats:** Five of the habitats in which this species occurred were swamps, four were streams, including a large stream (river), the Yarmouk River, and two habitats were springs (at Ein Om Ershid at Irbid, and Om Khlal Spring at Aqraba-Irbid).

**Parasitology:** *Lymnaea natalensis* is the intermediate host for the liver fluke *Fasciola gigantica* (see p. 78). This parasite infects herbivorous mammals, including sheep and especially cattle, and occasionally humans. *Lymnaea natalensis* is also the snail intermediate host for other nonhuman larval trematode parasites, some of which may cause cercarial dermatitis ("swimmer's itch") in man (see p. 10).

#### Subgenus *Fossaria* Westerlund

This subgenus contains the small lymnaeid species. Their shells are generally less than 13 mm in length, usually lack spiral sculpture, and are without a twist or plait on the columella. The dubious name *Galba* frequently has been used for this group of lymnaeid snails.

#### *Lymnaea (Fossaria) truncatula* (Müller)

The shell (Fig. 15) is small, 10 mm or less in length, rimately perforate, horn or tan in color, with well-rounded whorls and a broadly reflected columellar lip. The spire is broader and less acutely pointed than in *Lymnaea (Radix) natalensis*, and is about the same height as the shell aperture.

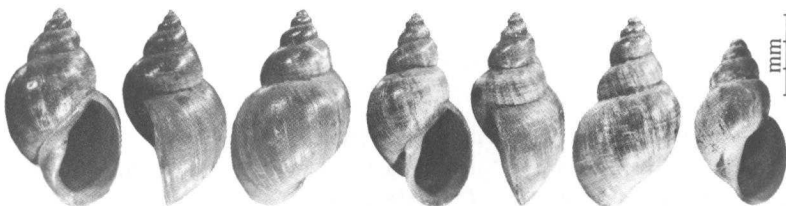


FIG. 15. Shell of *Lymnaea (Fossaria) truncatula*.

**General Distribution:** Europe, northern Asia and portions of Alaska and western Canada, the Near East, and Africa (where the species has a wide but discontinuous distribution).

**Distribution in Jordan** (Map 10, p. 162): Found rather widely scattered, from the Yarmouk River in the north to Ma'an Spring in the south. The most concentrated inhabitation is in the north, near the Yarmouk River.

**Habitats:** Most commonly found in springs. Other localities include streams (at Wadi Al-Sigin, Hartha-Irbid, and Zizon Spring), rivers (at Mohrbeen Spring, at Wadi Khaled at Irbid, and the Yarmouk River at Mokhibeh), a spring/pool (Hamed Spring), dam (Kafreen Dam) and a swamp (Mureihat Kated, Al-Ghour/Al-Karama).

**Parasitology:** *Lymnaea truncatula* is the intermediate host for the liver fluke *Fasciola hepatica* in many parts of the world, including Jordan (see p. 79). *Fasciola hepatica* is an important parasite of sheep and cattle, and is occasionally found in humans.

#### Family PHYSIDAE

The Physidae are mainly a family of North America, having only a few species occurring in Eurasia and Africa. The physids are readily recognized by a combination of several characters. Their lack of an operculum distinguishes them from all of the Prosobranchia. Their high-spired shell separates them from all of the Planorbidae, except the nonplanate members of the family (for example, *Bulinus*), and their sinistral (left-coiled) shell (see Fig. 80,a; p. 169) marks them as being different from the dextral Lymnaeidae. Their colorless body fluids and lack of a pseudobranch distinguishes them from the high-spired planorbids such as *Bulinus*.

The shells of physids are mostly high-spired, usually smooth and glossy or highly polished, and some genera, such as *Physella*, are distinguished by digitations on the mantle fringe, which, when the snail is active, extend out over part of the shell.

#### Genus *Physella* Haldeman

*Physella* is the largest genus of the family, with many species occurring in North America. One common, widespread species of Europe, *Physella acuta* [perhaps introduced from North America], is found now

in North Africa, the Near East and sub-Saharan Africa.

*Physella* is distinguished from the genus *Physa* (*sensu stricto*) by the sharply pointed tip of its spire, and digitations restricted to the parietal side of the mantle. The genus *Physa* has shells with rounded apical tips, and animals with mantle digitations on both sides.

*Physella acuta* (Draparnaud)

The sinistral shell (Fig. 16) is ovate, small to medium in size (length: 8 to 12 mm), with about 5 1/2 whorls, imperforate, pale horn in color, translucent, moderately glossy, nearly smooth, with fine growth lines and faint spiral sculpture. The shell aperture is more than half the total shell length. The outer lip of the aperture is sharp.

Because of the superficial similarity between the shells of *Physella acuta* and the medically significant *Bulinus truncatus*, it is important to be able to distinguish the two species. The shell of *Physella acuta* has a smoother appearance, a more polished surface and more sharply pointed apex. Its possession of mantle digitations and lack of both red blood and a pseudobranch further distinguish *Physella acuta* from *Bulinus truncatus*.



FIG. 16. Shell of *Physella acuta*.

**General Distribution:** Europe, North Africa and the Middle East; sub-Saharan Africa, Madagascar and various islands of the Indian Ocean (probably introduced); introduced into Japan, Australia, New Zealand and various Pacific islands, and parts of the United States. Reported from the Sinai Peninsula (as "*Physa subopaca* Lamarck") by Tchernov (1971).

**Distribution (Map 11, p. 162) and habitats in Jordan:** Common in

the Yarmouk and Jordan valleys in all types of aquatic habitats. Also, found in the King Talal Dam impoundment.

Elsewhere, Brown (1980) has reported *Physella acuta* as occurring most commonly in irrigation channels, dams and streams in or near towns in Africa. It is restricted to similar habitats in Australia, where recently it has been introduced (Burch, unpublished).

### Family PLANORBIDAE

The great majority of the planorbids have planate or discoidal shells (see Fig. 78,e; p. 168), as the name of the family implies. However, some members are nonplanate, i.e., are high-spired, including the genus *Bulinus*. In discoidal shells, the shell spire is flat or inverted below the level of the body whorl. Terminology in describing such a shell is shown in Fig. 17.

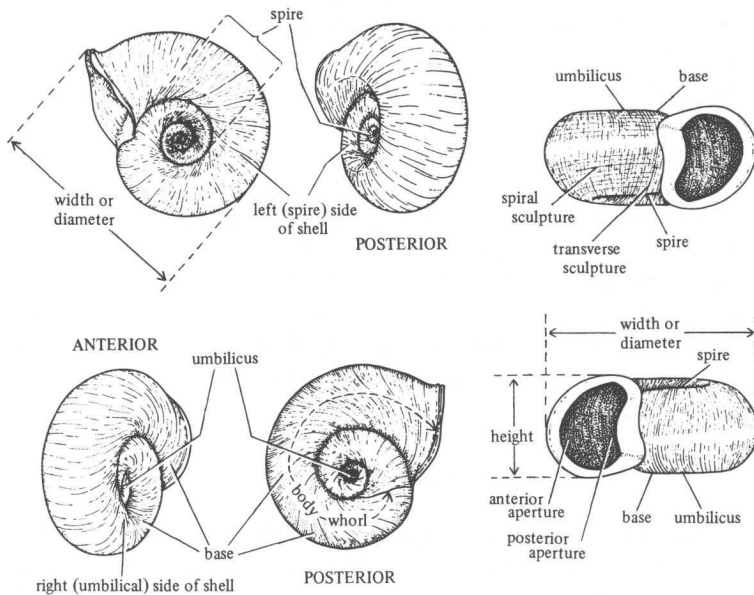


FIG. 17. Terminology of a planorbid shell.

The animals of all planorbid snails are sinistral, i.e., coiled to the left or in a counter-clockwise manner, and have respiratory, alimentary and

reproductive systems terminating on the left side (see Fig. 41; p. 57). A secondarily derived gill (pseudobranch) is situated on the left side of the animal near the breathing pore and in close proximity to the anus. The pseudobranch aids the mantle cavity in respiration.

A striking characteristic of nearly all planorbid snails is the possession of hemoglobin as the respiratory pigment of the blood. Nearly all other mollusks possess haemocyanin instead. The hemoglobin gives a reddish appearance to planorbid snails, if the red color is not masked by black pigments of the snails' skins. Albino snails, and those with very little black pigment, appear bright red.

#### Subfamily Planorbinae

The majority of the Planorbidae are members of the subfamily Planorbinae. Most of the members of this subfamily have discoidal shells, but a few species are high-spired. The Planorbinae are differentiated from the planorbid subfamily Bulininae by various anatomical characteristics, but especially by the terminal male genitalia (see p. 133), which in the Planorbinae includes a penis that is attached at only one end and projects freely into the lumen of the penis sheath.

#### Genus *Planorbis* Geoffroy

The family Planorbidae derives its name from this genus, and the type species of the genus, *Planorbis planorbis*, is described below. The genus usually can be distinguished from the wide-spread *Gyraulus* by its larger size (shells up to 16-20 mm in diameter). However, the diagnoses of the discoidal planorbid genera generally depend on characters of the reproductive system. In *Planorbis*, the penis is neither sclerotized nor has a stylet.

#### *Planorbis planorbis* (Linnaeus)

Shell (Fig. 18) discoidal, up to 8 mm in major diameter, with about 4 1/2 slowly increasing whorls, pale horn in color, with growth (transverse) lines, but without spiral striae. The inverted spire is flat, hardly depressed; the umbilical (upper-most) side is nearly flat. The whorls have a keel or sharp angulation at the periphery, a feature which easily distinguishes this species from local *Gyraulus*.



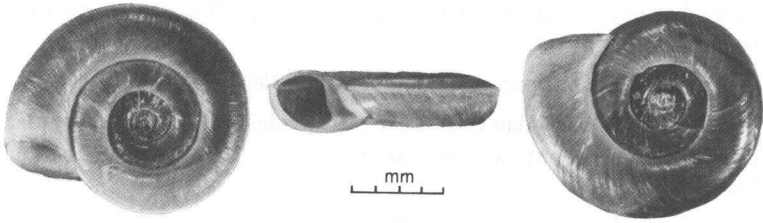


FIG. 18. Shell of *Planorbis planorbis*.

**General Distribution:** Europe, North Africa and southwest Asia, including Egypt, Jordan and Palestine.

**Distribution (Map 12, p. 163) and habitat in Jordan:** Found only in the swamp at Al-Azraq.

#### Genus *Gyraulus* Charpentier

The shells and animals of the genus *Gyraulus* are generally smaller than those of the genus *Planorbis*. In Jordan, no shells of *Gyraulus* have been found larger than 6 mm in diameter, and shells of most adult specimens do not get larger than 5 mm in major diameter. Anatomically, the penis of *Gyraulus* species have a small chitinized stylet at the tip.

#### *Gyraulus piscinarum* (Bourguignat)

Shell (Fig. 19) discoidal, small (adults with about 4 whorls measure about 5 mm in major diameter), pale horn colored, with well-developed growth lines but lacking spiral striae; spire inverted, the spire depression shallow and about  $\frac{1}{3}$  the major diameter of the shell; umbilical

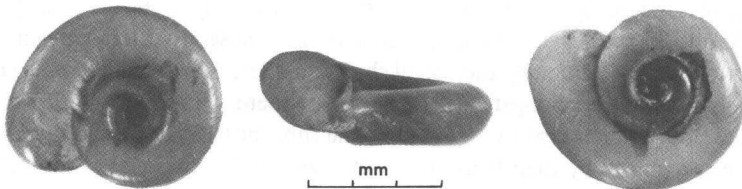


FIG. 19. Shell of *Gyraulus piscinarum*.

(upper-most) side slightly curved, with the umbilicus only a little depressed; whorls rounded; last part of the body whorl may or may not be deflected.

**General Distribution:** Asia Minor and the Near East.

**Distribution in Jordan** (Map 12, p. 163): Mainly in northwest Jordan in the Irbid area, but two populations occur in the south, at Aeil and Ma'an.

**Habitats:** Mainly associated with springs, but *Gyraulus* is also found in the river at Wadi Khaled at Irbid, in a stream at Wadi Al-Sigin at Hartha-Irbid, and in a swamp at Zour Al-Nees.

#### Subfamily Bulininae

The subfamily Bulininae contains two genera, *Bulinus*, which has a raised spire, and *Indoplanorbis*, which has an inverted spire (giving the shell a discoidal appearance). The subfamily is distinguished by its peculiar male terminal genitalis, which is a coiled tube, rather than the projecting phallate-type organ typical for the family. The tube is attached at both ends to the penis sheath and evaginates during copulation.

*Bulinus* is a genus of Africa and adjacent regions, where various of its species transmit the parasites causing urinary schistosomiasis. In central Africa, *Bulinus* species also transmit parasites causing a form of intestinal schistosomiasis. The other bulinine genus, the South Asian *Indoplanorbis*, has been rather widely distributed by human activities, and its distribution now includes southeastern Arabia (Wright & Brown, 1980).

#### Genus *Bulinus* Müller

The species of *Bulinus* are found in Africa and adjacent areas (in Southwest Asia, on some islands of the Mediterranean Sea and the Indian Ocean, and in the southern Iberian Peninsula). The shells are sinistral, have a raised spire, and are subglobose to narrowly elongate in shape. About 30 species are currently recognized. These are often segregated into three subgenera by their shell characteristics. The subgenus *Bulinus sensu stricto* has elongate, narrow shells, frequently sculptured with well-developed transverse ribs. Shells of the subgenus *Physopsis* usually can be recognized by their truncate columellas. Shells of species of the subgenus *Isidora* lack these features which characterize shells of the other two subgenera.

Subgenus *Isidora* Ehrenberg

The subgenus *Isidora* comprises two groups of species, the more northerly *Bulinus truncatus* group and the more southerly *Bulinus tropicus* group. In this subgenus, only species of the *Bulinus truncatus* group are intermediate hosts of parasites causing human schistosomiasis. Only one species of *Isidora*, *Bulinus truncatus*, occurs north of the Sahara and in the Near East.

*Bulinus truncatus* (Audouin)

Shell (Fig. 20) sinistral, small, about 10 mm in length (usually smaller), perforate, light horn in color, translucent, with impressed sutures. The shell is less glossy, its spire is not as pointed, the whorls are more shouldered and the aperture more roundly ovate than in *Physella acuta*. Also, the shell of *Bulinus truncatus* is perforate rather than imperforate.

The animal has red blood and a pseudobranch on the left side under the mantle collar and near the breathing pore and anus. These two characters easily distinguish *Bulinus truncatus* from *Physella acuta*, which has colorless blood and lacks a pseudobranch.

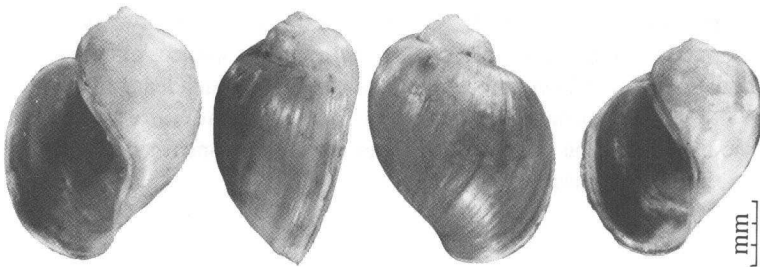


FIG. 20. Shell of *Bulinus truncatus*.

**General Distribution:** Africa north of the Sahara, from Morocco to Egypt (absent from some areas between); a few localities in the Iberian Peninsula of Europe; some of the Mediterranean islands (Sardinia, Sicily); the Near East (Arabia, Jordan, Palestine, Iran); sub-Saharan Africa (? as "*Bulinus truncatus rohlfsi*", "*Bulinus guernei*" and "*Bulinus coulboisi*"): Mauritania, Senegal, Ghana, Chad, Sudan, East Africa, Ethiopia).

**Distribution in Jordan** (Map 13, p. 163): Shaik Hussain Spring, Roman pools at Jarash, Ahmed Spring, Tal Sliman Shamahli, Zoor Al-Hamam, Muthalath Al-Masri, Zarka River and King Talal Dam, all in northwestern Jordan. Most recently, *Bulinus truncatus* has been found at Kafreen Dam in the Jordan Valley and in Om Khlal Spring near the Yarmouk River. All of these places have since been molluscicided.

**Habitats:** Except for the King Talal Dam and the Zarka River, *Bulinus truncatus* has been found in springs and associated pools and swamps.

**Parasitology:** Nearly everywhere *Bulinus truncatus* is found outside of Jordan, it serves as an intermediate host of parasites causing human urinary schistosomiasis.

#### Identification Key for the Freshwater Snails of Jordan

In an identification key as the one presented here, the reader with a snail to identify is presented with a successive series of two opposing choices about one or more characters of the shell or animal possessed by the snails whose identity is to be determined. In each successive set of opposing characters, only one of the opposing choices of characters should fit the specimen in question, the choice of which leads the reader to the next set of opposing characters. This procedure is followed until a couplet leads the reader to a species name. This species name identifies the snail in question.

- |   |   |   |
|---|---|---|
| 1 | Animal with an operculum (which seals the shell aperture when the snail's body is withdrawn into the shell) (Fig. 21) . . . . . | 2 |
|---|---|---|

Animal without an operculum to seal its shell aperture when withdrawn (Fig. 22) . . . . .	13
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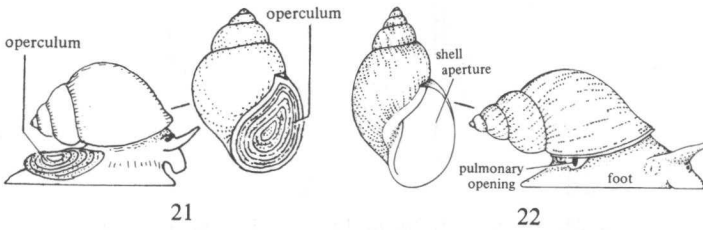


FIG. 21. Snail with an operculum. FIG. 22. Snail without an operculum.

2(1) Shell globose, neritiform in shape (Fig. 23,a) . . . . . 3

Shell of some other shape: depressed (Fig. 23,b),  
conical (Fig. 23,c) or discoidal (Fig. 23,d) . . . . . 4

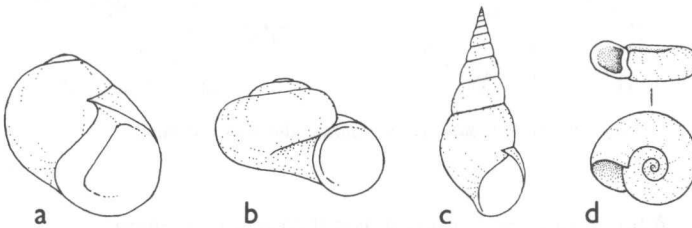


FIG. 23. Shell shapes. a, Neritiform; b, depressed; c, conical; d, discoidal.

53(2) Shell taller than broad; last whorl usually with a  
broad, shallow constriction (Fig. 24) . . . *Theodoxus jordani*

Shell globular, its height and width about equal; last  
whorl without a constriction (Fig. 25) . . *Theodoxus macrii*

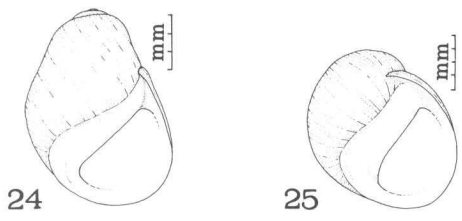


FIG. 24. *Theodoxus jordani*. FIG. 25. *Theodoxus macrii*.

4(2) Shell depressed, wider than high, small (Fig. 26) . . . . .  
..... *Valvata saulcyi*

Shell elongate, longer than wide . . . . . 5

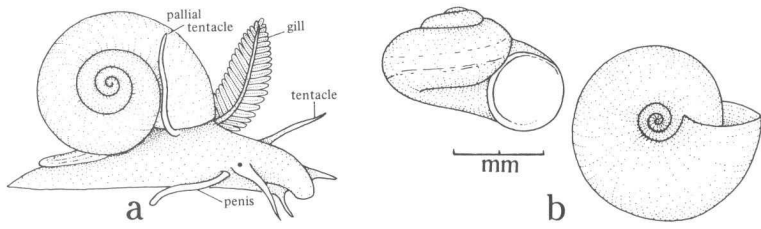


FIG. 26. *Valvata saulcyi*. a, Animal and shell; b, shell.

5(4) Adult shell small to minute, less than 6 mm in length . . . 6

Adult shell larger, small to large in size, more than  
6 mm in length . . . . . 10

6(5) Shell elongate (narrowly to elongately conic); spire  
long, 2/3 or more of the shell length . . . . . 7

Shell ovate (subovately to globosely conic); spire  
shorter, less than 2/3 of the shell length . . . . . 8

7(6) Shell with impressed sutures (Fig. 27) . . . *Semisalsa longiscata*

Shell with shallow sutures (Fig. 28) . . . *Semisalsa contempta*

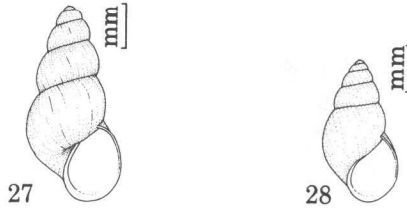


FIG. 27. *Semisalsa longiscata*. FIG. 28. *Semisalsa contempta*.

- 8(6) Shell subovately to subglobose conic, adult shell  
3 to 5 mm in length, imperforate (Fig. 29) .....  
..... *Pseudamnicola* sp.

Shell globose, adult shell 3 1/2 mm or less in length,  
perforate or narrowly umbilicate ..... 9

- 9(8) Shell very small, 2 1/2 to 3 1/2 mm in length (Fig.  
30) ..... *Pseudamnicola gaillardotii*

Shell minute, 1 to 1 3/4 mm in length (Fig. 31) .....  
..... *Pseudamnicola solitaria*

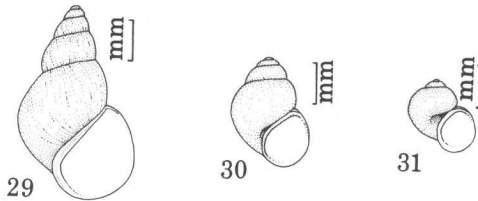


FIG. 29. *Pseudoamnicola* sp. FIG. 30. *Pseudoamnicola gaillardotii*. FIG. 31. *Pseudoamnicola solitaria*.

- 10(5) Shell narrowly conic, with spiral and transverse  
sculpture (Fig. 32) ..... *Melanoides tuberculata*

Shell broadly, globosely or elongately conic, smooth  
or with only transverse sculpture ..... 11

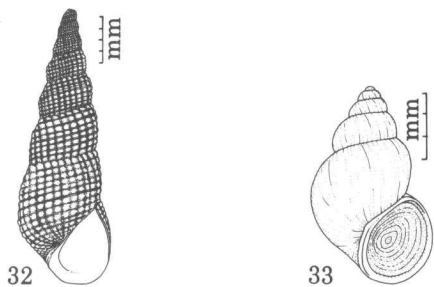


FIG. 32. *Melanoides tuberculata*. FIG. 33. *Bithynia philalensis*.

11(10) Anterior end of columellar lip continuous, not truncate (Fig. 33) . . . . . *Bithynia philalensis*

Anterior end of columellar lip of aperture truncate.  
*Melanopsis praemorsa* . . . . . 12

12(11) Shell smooth, without ribs (Fig. 34) . . . . .  
. . . . . *Melanopsis praemorsa buccinoidea*

Shell with strong transverse ribs (Fig. 35) . . . . .  
. . . . . *Melanopsis praemorsa costata*

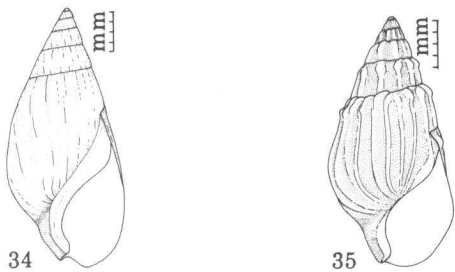


FIG. 34. *Melanopsis praemorsa buccinoidea*. FIG. 35. *Melanopsis praemorsa costata*.



13(1) Shell discoidal, with a sunken spire (Fig. 36) . . . . . 14

Shell high-spired (Fig. 37) . . . . . 15

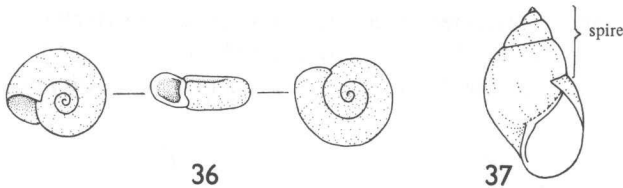


FIG. 36. Discoidal shell. FIG. 37. High-spired shell.

14(13) Shell with a keel or sharp angulation on the whorls  
(Fig. 38) . . . . . *Planorbis planorbis*

Shell with rounded whorls (Fig. 39) . . . *Gyraulus piscinarum*

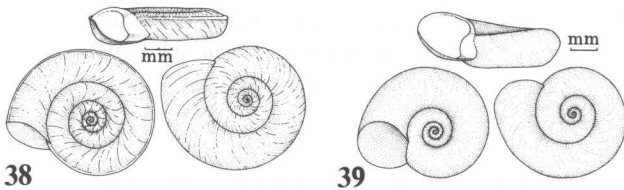


FIG. 38. *Planorbis planorbis*. FIG. 39. *Gyraulus piscinarum*.

15(13) Shell coiled to the right (dextral) (Fig. 40) . . . . . 16

Shell coiled to the left (sinistral) (Fig. 41) . . . . . 17

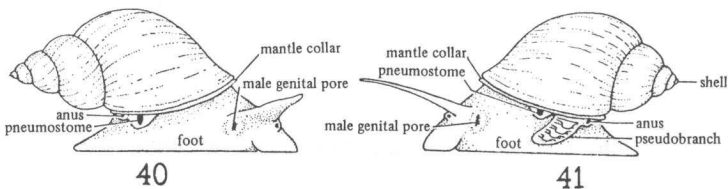
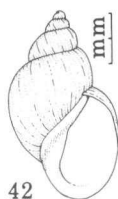


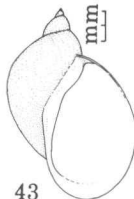
FIG. 40. Dextral animal and shell. FIG. 41. Sinistral animal and shell.

- 16(15) Shell small, adults less than 10 mm in length; spire relatively high and wide (Fig. 42) . . . . .  
 . . . . . *Lymnaea (Fossaria) truncatula*

Shell larger, medium in size, adults more than 10 mm and up to 15 mm or more in length; spire short and narrow (Fig. 43) . . . . . *Lymnaea (Radix) natalensis*



42

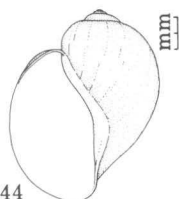


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FIG. 42. *Lymnaea (Fossaria) truncatula*. FIG. 43. *Lymnaea (Radix) natalensis*.

- 17(15) Shell a little rough, with rather deep sutures and a small umbilicus; animal with red blood, a pseudo-branch, and smooth mantle edge (Fig. 44) . . . . .  
 . . . . . *Bulinus truncatus*

Shell smooth, glossy, with shallow sutures and without an umbilicus; animal with colorless blood, lacking a pseudobranch, and with finger-like processes on the mantle edge (Fig. 45) . . . . . *Physella acuta*



44



45

FIG. 44. *Bulinus truncatus*. FIG. 45. *Physella acuta*.

### 5. Snail Intermediate Hosts of Human Schistosomes in the Near East and Africa

The purpose of the section to follow is to give an overview of the snails involved in schistosomiasis transmission in various parts of the Near East and Africa. Some of these snail species might possibly get transported to Jordan in the future, so a cursory knowledge of them is important. Most attention is given to the snails mediating schistosomiasis haematobium in the Near East, since these are most pertinent to possible disease establishment in Jordan.

Snail intermediate hosts for schistosome parasites causing human schistosomiasis in the Near Eastern/African region belong to two distinctly different freshwater snail genera. *Schistosoma haematobium*, causing schistosomiasis haematobium (also called vesical schistosomiasis or urinary schistosomiasis), has species of the snail genus *Bulinus* as intermediate hosts. These snails have elongated, left-spiraled shells and red blood. In West and Central Africa, several *Bulinus* species also are intermediate hosts of *Schistosoma intercalatum*, which causes a distinct type of intestinal schistosomiasis (schistosomiasis intercalatum). However, the main type of intestinal schistosomiasis, schistosomiasis mansoni, is caused by *Schistosoma mansoni*, which is transmitted by a different genus of snails, *Biomphalaria*. *Biomphalaria* species have medium-sized discoidal shells (and also have red blood). *Bulinus* and *Biomphalaria* are the only snail genera that contain species that are intermediate hosts of human schistosomes in the Near East and Africa.

#### Snail Intermediate Hosts of *Schistosoma haematobium* (Urinary Schistosomiasis)

The snail genus *Bulinus* contains a large number of species, most of which are found only in Africa. The genus has been divided by parasitologists into four species groups: 1) the *Bulinus tropicus/truncatus* group, 2) the *Bulinus forskalii* group, 3) the *Bulinus reticulatus* group, and 4) the *Bulinus africanus* group. These four species groups form three subgenera of the genus *Bulinus* (see Figs. 46-48, p. 61): the subgenus *Isidora* contains the *Bulinus tropicus/truncatus* group; the subgenus *Bulinus sensu stricto* contains the *Bulinus forskalii* and the *Bulinus reticulatus* groups; and the subgenus *Physopsis* contains the *Bulinus africanus* group.

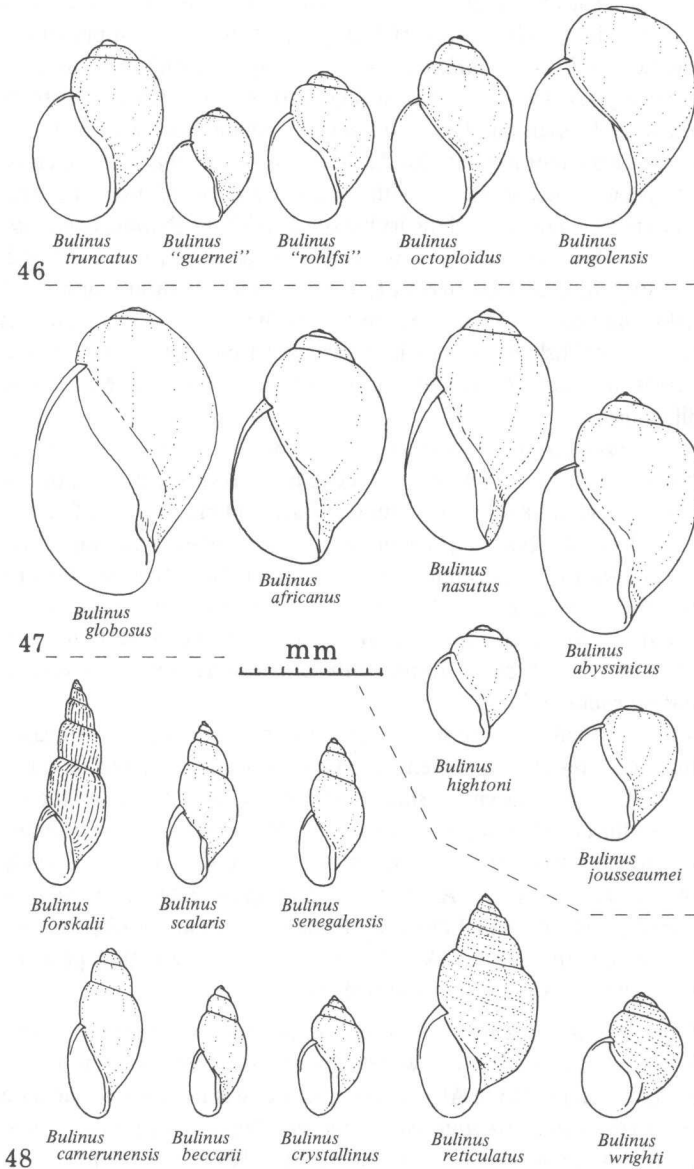
### The Near East

Three species groups of *Bulinus* are represented in the Near East as intermediate hosts of *Schistosoma haematobium*: *Bulinus truncatus* (of the *Bulinus tropicus/truncatus* group), *Bulinus beccarii* (of the *Bulinus forskalii* group) and *Bulinus wrighti* (of the *Bulinus reticulatus* group). Each of these three species is discussed below.

*Bulinus truncatus* is the most widespread of the intermediate hosts of *Schistosoma haematobium* in the Near East, where it has been reported from Jordan, Lebanon, Syria, Iraq, Iran\*, North Yemen, South Yemen, Saudi Arabia and Palestine. *Bulinus truncatus* is also the snail host of *Schistosoma haematobium* in northern Africa.

*Bulinus truncatus* has a highly variable shell, with both the size of the shell and the height of its apex varying between populations. In the Near Eastern countries, *Bulinus truncatus* can be distinguished from both *Bulinus beccarii* and *Bulinus wrighti* (the other two intermediate hosts of *Schistosoma haematobium* in the region) with a minimum of difficulty. The shell of *Bulinus truncatus*, in outline, is intermediate in shape between *Bulinus beccarii* and *Bulinus wrighti*, being rounder and narrower than *Bulinus beccarii* and not as globose as *Bulinus wrighti*. Also, *Bulinus truncatus* attains a greater size than either *Bulinus beccarii* or *Bulinus wrighti*. *Bulinus truncatus* is generally 13-15 mm in shell length (as compared to approximately 7 mm for the other two species) and 8-10 mm in width (although various populations or individuals may be larger or smaller than this). The shell whorls are generally less rounded than those of *Bulinus wrighti* and have a flattened appearance. The apex of the shell of *Bulinus truncatus* may be moderate in length (generally), or it may be short. In contrast to *Bulinus wrighti*, which has a wide umbilicus, *Bulinus truncatus* has a narrow umbilicus, and the shell is generally heavier and thicker than the shell of *Bulinus wrighti*. The distributions of *Bulinus truncatus* and *Bulinus wrighti* overlap only in southwestern Arabia. Due to the spotty distribution of *Bulinus wrighti* and its narrow ecological requirements, *Bulinus truncatus* and *Bulinus wrighti* are unlikely to be found in the same habitat. For the same reasons, *Bulinus wrighti* probably will not be found outside of its natural area of distribution, and introductions by human or other agencies to other parts of the Near East are not likely.

\*Although Iran is not a Near Eastern Country, it is included here because of its proximity to the region, and because it also has endemic schistosomiasis.



FIGS. 46-48. Shells of various *Bulinus* species. FIG. 46. Species of the *Bulinus* subgenus *Isidora*. FIG. 47. Species of the *Bulinus* subgenus *Physopsis*. FIG. 48. Species of the *Bulinus* subgenus *Bulinus* s.s.

One reason for the widespread distribution of *Bulinus truncatus* is its ability to live in a wide variety of habitats and under a number of environmental conditions. *Bulinus truncatus* may be found in permanent and temporary lakes and ponds, in springs, streams and rivers, in cisterns and in artificial canals and lakes. In fact, man-made lakes and irrigation canals make excellent habitats for *Bulinus truncatus*. *Bulinus truncatus* is a snail species which is able to withstand desiccation, allowing the species to survive even the complete drying of its habitat. *Bulinus truncatus* is very adaptable and its spread to man-made lakes is to be expected, since the impoundment of rivers often makes ideal habitats for a rapid population increase, even in areas in which the aquatic vegetation has not become established. Canals in which water current is slow are also prime areas in which *Bulinus truncatus* can and has become established and will flourish.

*Bulinus truncatus* is most likely to be found in shallow water. In large lakes, it will be found near the edge in areas where wave action is not severe. It is unlikely to be found in fast-flowing regions of rivers, streams and canals, but may be in the portions of fast-flowing water where vegetation is dense enough to counteract the effects of the fast current, where other means of protection are present, or in regions or pockets where water current is slower. It is not necessary that thick vegetation be present, since *Bulinus truncatus* can live on sparse vegetation, and on rocks and logs.

A major difficulty in the successful eradication of *Bulinus truncatus* from infested sites is its excellent ability to reproduce by self-fertilization, so that a single surviving snail may repopulate a site after the effects of molluscicides have been removed. Since the snails may crawl from the water onto emergent vegetation, stones, logs, etc., it is likely that some will avoid death. After the water is again suitable for survival of the snails, one or a small number of snails easily can rapidly repopulate the treated site. This makes it extremely important that periodic surveillance be part of any snail control project.

*Bulinus beccarii* is a member of the *Bulinus forskalii* group of species. *Bulinus forskalii*, the most widely distributed member of the group, is generally restricted to the African continent and is not an intermediate host for *Schistosoma haematobium*. *Bulinus beccarii* is, however, susceptible to infection by *Schistosoma haematobium* and is one of the intermediate hosts for this parasite in southwest Arabia. *Bulinus beccarii* is present in perennial streams and springs with high calcium content, and can withstand long periods of drought. They are also present in man-made waterways. They are not usually found living with *Bulinus*

*truncatus*, but have been reported to do so on the Red Sea coast of Saudi Arabia. *Bulinus beccarii* is present in Saudi Arabia, North Yemen and South Yemen, but it is apparently absent from Oman or southeast Arabia.

The snails of the *Bulinus forskalii* group possess a narrow shell with a long spire, and the shell is distinctly longer than wide. *Bulinus beccarii* is similar to *Bulinus forskalii*, but *Bulinus beccarii*'s shell is generally smaller, and has a wider body whorl and a shorter spire. The shell of *Bulinus beccarii* is elongated, its width approximately one-half of its length, giving the shell a narrow appearance. The length of the shell is approximately 6-7 mm, its width approximately 3.5 mm. The suture lines between the whorls are deeply indented. *Bulinus beccarii* is distinct from both *Bulinus truncatus* and *Bulinus wrighti*, the two other intermediate hosts for *Schistosoma haematobium* in the Near East, since both of the latter species possess a more rounded shell which is not distinctly narrow as is the shell of *Bulinus beccarii*. *Bulinus beccarii* is anatomically typical of other bulinine snails in possessing red blood, a pseudobranch, a sinistral shell and an ultrapenis in the reproductive system.

*Bulinus wrighti* is one of two species in the *Bulinus reticulatus* group, the other being *Bulinus reticulatus* of Africa. *Bulinus wrighti* is restricted to the Arabian peninsula and is found in South Yemen, Oman and Saudi Arabia. *Bulinus wrighti* is found in oases, springs and temporary pools on stones and is reported from relatively few localities. It is the intermediate host for *Schistosoma haematobium* in South Yemen and possibly elsewhere. In addition to being a host of *Schistosoma haematobium*, it can be infected by a number of other human and nonhuman schistosome species related to *Schistosoma haematobium* (*Schistosoma intercalatum*, *Schistosoma bovis*, *Schistosoma mattheii* and *Schistosoma margrebowiei*).

The shell of *Bulinus wrighti* is translucent when fresh, and is rather small. It has a large globular body whorl with a distinctly pronounced spire. Shells are approximately 5-7 mm in length and approximately 4.5-7 mm in width. The large body whorl makes the shell nearly as wide as it is long and gives the shell its globular appearance. The shell has a broadly reflexed, straight columella and a large, wide umbilicus. The shells have a markedly reticulate sculpture formed by spiral grooves which intersect with the ribs of the shell. The translucence of fresh shells means that close examination of the shell is necessary to clearly observe the reticulation.

The importance of *Bulinus wrighti* in the diffusion of schistosomiasis lies mainly in its wide susceptibility to a number of strains of *Schistosoma haematobium* and to other species of related schistosomes. This susceptibility is, however, tempered by the rather spotty distribution and the snail's apparently narrowly restricted ecological requirements, which would appear to make control measures more easily applied than in the case of other more widely distributed species such as *Bulinus truncatus*.

### Africa

In Africa, species of all four groups of *Bulinus* transmit *Schistosoma haematobium*. However, the most important intermediate hosts belong to the *Bulinus tropicus/truncatus* group (*Bulinus truncatus*) and the *Bulinus africanus* group (*Bulinus africanus* and *Bulinus globosus*). North of the Sahara, only *Bulinus truncatus* is present. In Africa south of the Sahara, *Bulinus truncatus* is present primarily in the northern part, where it mediates urinary schistosomiasis. *Bulinus africanus* and *Bulinus globosus* are present only south of the Sahara Desert, with *Bulinus africanus* generally being restricted to the eastern part of the region. *Bulinus globosus* is widespread over much of Africa south of the Sahara.

### Snail Intermediate Hosts of *Schistosoma mansoni* (Intestinal Schistosomiasis)

The intermediate hosts for *Schistosoma mansoni* are members of the snail genus *Biomphalaria*. The genus *Biomphalaria* is divided into four species groups (see Figs. 49-52, p. 66): the *Biomphalaria sudanica* group, the *Biomphalaria pfeifferi* group, the *Biomphalaria alexandrina* group and the *Biomphalaria choanomphala* group.

### The Near East

Only one species of *Biomphalaria* is present in the Near East, *Biomphalaria arabica*, a member of the *Biomphalaria pfeifferi* species group. (This species simply may be only a local form of *Biomphalaria pfeifferi*.) *Biomphalaria alexandrina* was reported previously from Palestine, but it apparently no longer occurs there. *Biomphalaria arabica* has been



found in Saudi Arabia, Oman, North Yemen and South Yemen. It occurs in perennial and intermittent streams, seepages, springs, oases, cisterns and man-made waterways. The shell of *Biomphalaria arabica* is discoidal, that is, it has a flat shell without an elevated spire. It is about 10-15 mm in diameter and 4 mm high.

## Africa

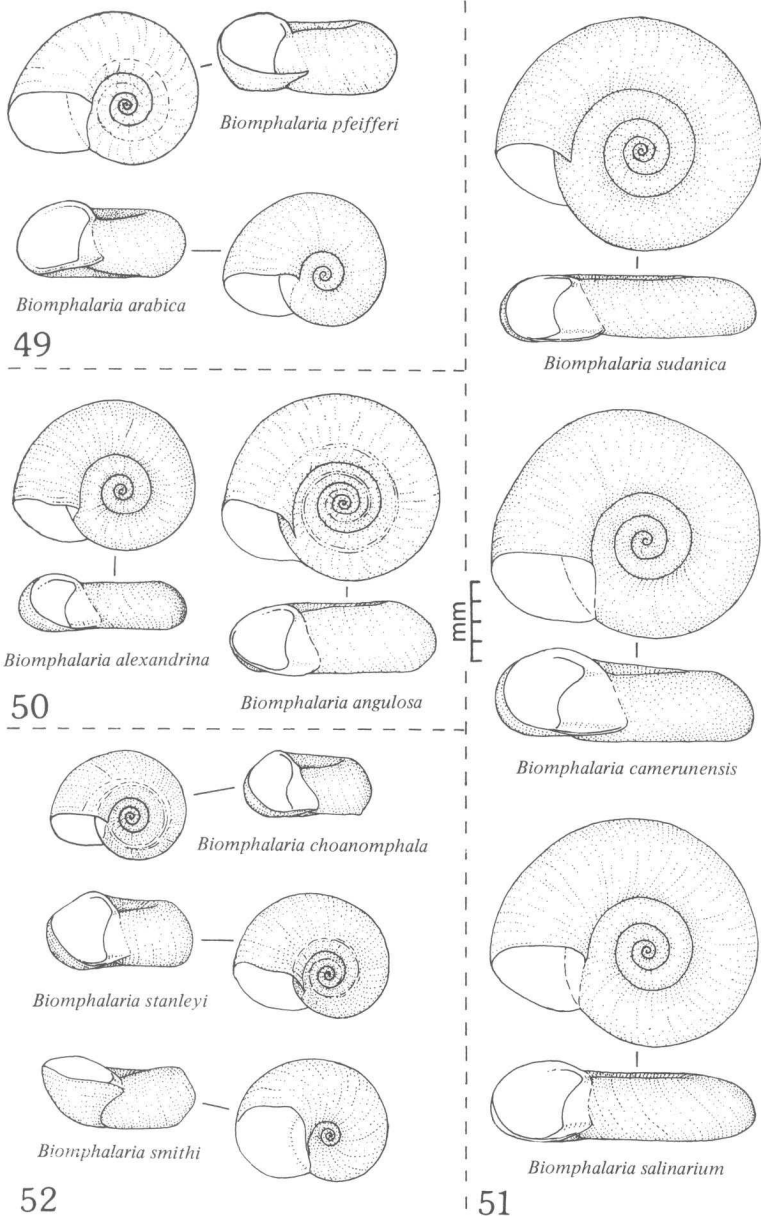
There are a number of species of *Biomphalaria* in Africa, all very similar in appearance. The most widely distributed is *Biomphalaria pfeifferi*, which occurs in northern Africa in Algeria, Libya, Mauritania, Mali, Niger and Chad, and in Africa south of the Sahara from Senegal in the west to Sudan, Ethiopia and Somalia in the east, and to Namibia, South Africa and Madagascar in the south. *Biomphalaria pfeifferi* is found in natural and man-made streams of various sizes (including irrigation canals) and in man-made impoundments. It is apparently absent from large swamps and small seasonal pools, and from areas with cool winters and low rainfall, and from areas with high summer temperatures.

Because of its wide distribution, *Biomphalaria pfeifferi* is the most important intermediate host of its genus in Africa. The shells of adults range from about 10 mm to 17 mm in diameter, and from about 4 mm to 5 mm in height. On the spire side of the shell, the whorls are bluntly angular and the spire depression occupies about 1/3 of the shell diameter.

The species of *Biomphalaria* of the upper Nile is *Biomphalaria alexandrina*, which mediates *Schistosoma mansoni* in Egypt. This snail also has a limited occurrence in Sudan, where it may also contribute to infection of humans with schistosomes. *Biomphalaria alexandrina* prefers slowly flowing irrigation canals which provide stable conditions. It is distinguished from *Biomphalaria pfeifferi* by several minor morphological differences, mainly its relatively long penis sheath and angular lateral teeth mesocones.

*Biomphalaria angulosa* occurs in seasonal swamps in Tanzania, Zambia and Malawi, and is susceptible to infection by *Schistosoma mansoni* from that region. The shell of *Biomphalaria angulosa* is relatively high, and its whorls on both sides of the shell have conspicuous angulations.

*Biomphalaria sudanica* is found in Chad, Sudan, Ethiopia, Kenya, Uganda, Tanzania, Zambia and Zaire, occurring in more or less perennial swamps. It is similar in size to *Biomphalaria pfeifferi*, but occasionally may get larger (up to 22 mm in shell diameter).



FIGS. 49-52. Shells of various *Biomphalaria* species. FIG. 49. Species of the *Biomphalaria pfeifferi* species group. FIG. 50. Species of the *Biomphalaria alexandrina* species group. FIG. 51. Species of the *Biomphalaria sudanica* species group. FIG. 52. Species of the *Biomphalaria choanomphala* species group.

*Biomphalaria camerunensis* is found from Ghana eastward to the Central African Republic and Zaire, occurring on mud bottoms in shallow, standing or flowing waters with aquatic vegetation. The shell of *Biomphalaria camerunensis* is similar to *Biomphalaria sudanica*, but is less depressed.

*Biomphalaria salinarum* is found in Angola and Namibia. Its shell resembles that of *Biomphalaria sudanica*, but its radulae differ by having lateral teeth with angular mesocones.

*Biomphalaria choanomphala* occurs in lakes Victoria, Kyoga and Albert, and in the Victoria Nile and Albert Nile rivers. It is found in shallow water on various types of substrates, particularly on gravel and stones, but also on mixed sand and mud. It is a small species, less than 10 mm in diameter, with high whorls that are angular on the spire side and sometimes on the umbilical side.

*Biomphalaria smithi* is found in Uganda in Lake Edward and Mirambi crater lake on aquatic vegetation. Its shell is characterized by a relatively narrow umbilicus and steeply descending last 1/4 whorl.

*Biomphalaria stanleyi* occurs in Lake Albert in Uganda and Zaire, in Lake Chad, and in Lake Tshohoha in Ruanda. Its habitat has been reported to be aquatic vegetation in shallow water. Its shell is characterized by high, rapidly increasing whorls which are angulated on top and bottom.

#### Snail Intermediate Hosts of *Schistosoma intercalatum* (Intestinal Schistosomiasis)

*Schistosoma intercalatum* apparently consists of two different strains of parasite, each with a different species group of *Bulinus* snail serving as intermediate hosts. In western Africa, including Gabon and Cameroon, a strain of *Schistosoma intercalatum* can infect members of the *Bulinus forskalii* group (*Bulinus forskalii*, *Bulinus senegalensis*, *Bulinus camerunensis*, *Bulinus crystallinus* and *Bulinus scalaris* are susceptible), as well as *Bulinus wrighti* of the *Bulinus reticulatus* group. A second strain of *Schistosoma intercalatum* is found in eastern Zaire. This strain does not infect snails of the *Bulinus forskalii* group, but can develop in species of the *Bulinus africanus* group (*Bulinus africanus*, *Bulinus globosus* and *Bulinus hightoni*), as well as *Bulinus wrighti* of the *Bulinus reticulatus* group. In nature, the Cameroon strain has as intermediate

hosts *Bulinus forskalii* and *Bulinus camerunensis*, and the eastern Zaire strain has *Bulinus africanus* and *Bulinus globosus*.

#### Distribution of Schistosome Snail Intermediate Hosts in the Near East and Africa

##### The Near East

There are four species of snails which act as intermediate hosts of schistosomes in the Near East. These are *Bulinus truncatus*, *Bulinus beccarii* and *Bulinus wrighti*, which are intermediate hosts of *Schistosoma haematobium*, and *Biomphalaria arabica*, which is the intermediate host of *Schistosoma mansoni*.

##### Jordan

Jordan has been fortunate in having been spared, at least in modern times, the misery caused by the most prevalent and serious of the snail-mediated human diseases, schistosomiasis. One of the reasons for this blessing in a region plagued by the disease is that the snails mediating schistosomiasis have not become established in the country, or their occurrence has been very limited and sporadic. However, in recent years the snail hosts of urinary schistosomiasis have been found at several localities in the country, and due to the activities of well-known snail dispersal agents — birds and humans — the discovery of more occurrences in Jordan of snails susceptible to human schistosomes might be expected. Also, now that there has been a change in the nature of available habitats for snails in Jordan, the ability of introduced snails to survive and flourish is probably much better now than it has been in the past.

Schistosome intermediate hosts were first discovered in Jordan in 1975, when a single focus of *Bulinus truncatus* was found in a small cement reservoir at Muthalath Al-Masri about 13 km south of Dier Alla. Although this population was eradicated, further populations of *Bulinus truncatus* have since been found at various places (Map 13, p. 163; p. 166). *Bulinus truncatus* has not been found in the main irrigation canals of Jordan, nor in the Jordan River. However, it found its way into the King Talal Dam impoundment, where it has been difficult to eradicate.

##### Lebanon

*Bulinus truncatus* is present in the areas along the Litani River in the

south of Lebanon and in the coastal regions from Sur to Saida. *Biomphalaria* does not occur in Lebanon.

### Syria

*Schistosoma haematobium* is present in Syria, and its intermediate host, *Bulinus truncatus*, is distributed in areas along the drainage of the Orentes River, along the Kabour River and its tributaries in the Koubour-el-Beid and Kamisli areas, along the Balikh River in the Tell Abiad area and Raqqah subdistrict, and along the Euphrates River from Raqqah southwest to the border with Iraq. *Biomphalaria* and *Schistosoma mansoni* are not found in Syria.

### Iraq and Iran

The major distribution of *Bulinus truncatus* in Iraq is along the Tigris and Euphrates rivers, and the tributaries of the Tigris River. *Bulinus truncatus* may be found along the Tigris River, beginning in the region of Mosul and along the Great Zab, Lesser Zab and Diyala rivers, which are tributaries of the Tigris. The snails are present along the Tigris southward to a point immediately south of Basra. *Bulinus truncatus* is found along the course of the Euphrates River from the vicinity of Raqqah, Syria, and continues throughout Iraq to the union of the Euphrates and Tigris rivers. The snail does not appear to be present in the rivers themselves (that is, in the Tigris, Euphrates, Great Zab, Lesser Zab and Diyala rivers) but, instead, occurs in marshes and swamps and, especially, in irrigation schemes. The snail is very common in the Amara swamps.

The upper, or northern, valley of the Tigris River in Iraq is not generally inhabited by *Bulinus truncatus*, since environmental conditions are such that suitable habitats are less frequent. Localities reported for *Bulinus truncatus* in this area are sporadically distributed and limited.

In Iran, *Bulinus truncatus* is found only in the Khuzistan region in the southwestern part of the country. The major focus is in an area along the Karkheh and Dez rivers, from Dezful in the north to near Ahwaz in the south. A second area is along the lower Karkheh River, extending from the Iraq-Iran border to the confluence of the two branches of the lower Karkheh River near Hamidieh. This area includes an extension of the Amara marshes between Amara, Iraq, and Ahwaz, Iran. Other foci have been found in the upper Karun watershed near

Sardasht and Shushtar, and in the Bala Rud Stream watershed, a tributary of the Dez River, near Heydarkhan.

*Biomphalaria* and *Schistosoma mansoni* are not found in either Iraq or Iran.

The Arabian Peninsula (including Saudi Arabia, North Yemen, South Yemen, Oman, United Arab Emirates, Kuwait and Qatar)

Three species of *Bulinus*, all potential or actual intermediate hosts of *Schistosoma haematobium*, are present on the Arabian Peninsula. These three species are *Bulinus beccarii*, *Bulinus wrighti* and *Bulinus truncatus*. *Bulinus beccarii* is found in the southwest region of the peninsula, in Saudi Arabia, and in North and South Yemen. *Bulinus wrighti* is reported from few, widely scattered localities in Saudi Arabia, South Yemen and Oman. *Bulinus truncatus* is present in the western area of Saudi Arabia and North and South Yemen.

*Biomphalaria arabica* (possibly only a local form of *Biomphalaria pfeifferi*) has a wide distribution throughout much of Saudi Arabia, and North and South Yemen, and is also present in Oman.

#### Palestine

*Bulinus truncatus* is widespread in Palestine north of Jerusalem, but is not present in the Sea of Galilee (Lake Kinnereth) and is generally absent from the Negev and the Arava Valley.

No intermediate hosts of *Schistosoma mansoni* are present in the country. *Biomphalaria alexandrina* has been reported from one locality on the Yarkon River in northern Palestine, but it is no longer found there.

#### North Africa and Egypt

##### Egypt

The intermediate host for *Schistosoma haematobium* in Egypt is *Bulinus truncatus*. It is distributed throughout the length of the Nile River, including Lake Nasser in southern Egypt. The snail is widely distributed in the Nile River, as well as in the Egyptian irrigation schemes, and was also found in the Kharga, Dakhla and Baharia oases.

Previously, *Biomphalaria alexandrina* was confined to the delta region

of the Nile River in northern Egypt. Recently, however, it has been found south of Cairo in Menia Province, and even more recently has been found at the city of Aswan in southern Egypt.

### Libya

Libya is relatively free of intermediate hosts of human schistosomes. *Bulinus truncatus* has been found in the Sebha region (Fezzan area) in southern Libya, and isolated populations of *Biomphalaria pfeifferi* have been reported at Ghat and Taurorga.

### Tunisia

In Tunisia, the only intermediate host of human schistosomes is *Bulinus truncatus*, which is most common in the Chott Djerid region, but is generally distributed in the middle to northern part of the country.

### Algeria

*Bulinus truncatus* is distributed in the northern coastal region of Algeria, but it has also been reported at Djanet oasis, Hoggar oasis, Macta, Mazafran, Mirabeau, Oued Souman, Lake Oubeira and Anegid. The snail is most common at Inkemann-Saint Aimé and Foundouk.

*Biomphalaria pfeifferi* has only limited distribution in Algeria. It is reported from Tassisi N'Ajjer and Tin Tahart.

### Morocco

Only the intermediate host of *Schistosoma haematobium* is present in Morocco. *Bulinus truncatus* is reported from a number of localities. It appears to be generally distributed throughout the country, but is more common near the coast and in the south.

### Western Sahara

No intermediate hosts of human schistosomiasis are present in Western Sahara.

### Mauritania

Three species of *Bulinus* which may serve as intermediate hosts for

*Schistosoma haematobium* are present in Mauritania. These species are *Bulinus senegalensis*, *Bulinus truncatus* (also called "*Bulinus guernei*") and *Bulinus jousseaumei*. All are present in the extreme southern part of Mauritania, but *Bulinus truncatus* is also reported from the south-west of Mauritania.

Snail intermediate hosts for *Schistosoma mansoni* are not present in Mauritania.

### Sudan

Intermediate hosts of both *Schistosoma haematobium* and *Schistosoma mansoni* are present in Sudan. Two species of *Bulinus* are present, of which the most widely distributed is *Bulinus truncatus*, which occurs along the Nile River from the border with Egypt, along the Blue Nile east to Roseires and along the White Nile to the border with Uganda. *Bulinus truncatus* is less common in the southern part of the country. The second species of *Bulinus* which is an intermediate host of *Schistosoma haematobium* in Sudan is *Bulinus globosus*. It is restricted to southern Sudan (Equatoria Province).

Three species of *Biomphalaria* are present in Sudan, *Biomphalaria alexandrina*, *Biomphalaria sudanica* and *Biomphalaria pfeifferi*. All serve as intermediate hosts for *Schistosoma mansoni*.

*Biomphalaria alexandrina* has been reported in a limited forci along the Nile River from Khartoum to Kosti. However, *Biomphalaria sudanica* and *Biomphalaria pfeifferi* are the common *Biomphalaria* species in the Sudan. *Biomphalaria pfeifferi* is widely distributed south of the confluence of the Atbara and Nile rivers to the border with Uganda. Its distribution overlaps that of both *Biomphalaria alexandrina* and *Biomphalaria sudanica*. *Biomphalaria sudanica* is distributed south of Shambat to the Ugandan border, and is restricted to the White Nile drainage. *Biomphalaria sudanica* inhabits swamps and small seasonal pools, while *Biomphalaria pfeifferi* inhabits other types of water, such as irrigation canals, man-made lakes, streams and seepages, which can be much the same type of habitat in which *Biomphalaria alexandrina* may be found. The difference in habitat preferences of *Biomphalaria pfeifferi* and *Biomphalaria sudanica* make it unlikely that the two species will be found together, even though their range of distributions, in large part, overlap.

### Ethiopia

A large number of potential or actual intermediate hosts for both



*Schistosoma haematobium* and *Schistosoma mansoni* are present in Ethiopia. Five species of *Bulinus* which are potential intermediate hosts of *Schistosoma haematobium* occur in the country: *Bulinus abyssinicus*, *Bulinus truncatus*, *Bulinus octoploidus*, *Bulinus africanus* and *Bulinus reticulatus*. *Bulinus abyssinicus* is restricted to marshes along the middle and lower Awash River. *Bulinus truncatus* is present in irrigation systems in the Awash Valley, lakes in the southern Rift Valley and streams in the highlands. *Bulinus octoploidus* is present near Addis Ababa, Dessie and north of Gondar. *Bulinus africanus* is present at Jimma, in Lake Tana and northeast of Gondar (Medhanie Alem). *Bulinus reticulatus* is found north of Gondar.

*Biomphalaria pfeifferi* and *Biomphalaria sudanica*, both intermediate hosts for *Schistosoma mansoni*, are present, with *Biomphalaria pfeifferi* being more widely distributed than *Biomphalaria sudanica*. *Biomphalaria pfeifferi* is widespread south of Asmara and west of the 40th meridian. It is also present in a geographical band running through mid-Ethiopia into Somalia. *Biomphalaria sudanica* has been reported in lakes Zwai, Awasa and Margherita.

#### Somalia

*Bulinus abyssinicus* is the intermediate host of *Schistosoma haematobium* in Somalia and is present in the south, from the lower Uebi River basin southwards nearly to the border with Kenya, including the river basins of the Shebeli and Giuba rivers and in lakes near the border of Kenya. Although in Ethiopia *Bulinus abyssinicus* is restricted to marshy areas, in Somalia it occurs in lakes, canals and drains. *Biomphalaria pfeifferi* is present only in the northwest region of Somalia, in the Hargesia district.

#### Chad

Three species of *Bulinus* which may serve as intermediate host for *Schistosoma haematobium* have been reported from Chad. *Bulinus globosus* has approximately the same distribution as *Biomphalaria pfeifferi* (see below), except that it is not present at Faya-Largeau or in Lake Chad. *Bulinus truncatus* also has nearly the same distribution as *Biomphalaria pfeifferi*, including being present in Lake Chad and at the Faya-Largeau oasis. The third species is *Bulinus jousseaumei*, which has been reported from the Lake Chad area.

Three species of *Biomphalaria* which can serve as intermediate hosts for *Schistosoma mansoni* are present in Chad. These are *Biomphalaria pfeifferi*, *Biomphalaria sudanica* and *Biomphalaria stanleyi*. *Biomphalaria stanleyi* is found only in Lake Chad. *Biomphalaria pfeifferi* is found in Lake Chad and is also widespread south of a line extending from Lake Chad to the Sudanese border, including the Samalai River drainage. It is found also at the oasis of Faya-Largeau in northern Chad. *Biomphalaria sudanica* also occurs in Lake Chad, and is distributed in a belt in a line from Lake Chad at the Sudanese border and south approximately to the Samalai River. *Biomphalaria sudanica* is not present in southern Chad.

West Africa (including Niger, Mali, Senegal, Gambia, Guinea-Bissau, Guinea, Sierra Leone, Liberia, Upper Volta, Ivory Coast, Ghana, Togo, Benin, Cameroon and Nigeria)

In the countries of western Africa, intermediate hosts for *Schistosoma haematobium*, *Schistosoma mansoni* and *Schistosoma intercalatum* are present.

Five species of *Bulinus* which may serve as intermediate hosts for *Schistosoma haematobium* are present in western Africa. *Bulinus truncatus* (which includes "*Bulinus guernei*" and "*Bulinus rohlfsi*") and *Bulinus globosus* are the most widespread of the *Bulinus* species and occur in the region south of the Sahara. *Bulinus jousseaumei* has scattered occurrence from Chad to Senegal, with a northerly distribution, primarily in a belt along the Niger River in Niger and Mali and west to Senegal. It is not found in the southern coastal region of this area, nor in Cameroon. *Bulinus camerunensis* is found in west Cameroon in lakes Barombi Kotto and Debundsha. *Bulinus senegalensis* is generally restricted to Gambia, Senegal and southern Mauritania.

In Cameroon, the intermediate host for *Schistosoma intercalatum* is *Bulinus forskalii*, which is widely distributed throughout Cameroon and much of Africa. *Bulinus camerunensis* is also susceptible to *Schistosoma intercalatum*.

The intermediate hosts for *Schistosoma mansoni* are *Biomphalaria pfeifferi* and *Biomphalaria camerunensis*. *Biomphalaria pfeifferi* is the more widely distributed, being present in all countries in the region south of the Sahara, but in Niger it is restricted to the extreme southern tip, along the Niger River. *Biomphalaria camerunensis* occurs along the coastal areas of western Africa from Ghana through the southern half of Cameroon.

Central Africa (including Central African Republic, Equatorial Guinea, Gabon, Congo Republic, Zaire, Angola and Namibia)

Three intermediate hosts of *Schistosoma haematobium* are present in this region. These are *Bulinus globosus*, *Bulinus africanus* and *Bulinus truncatus*. *Bulinus globosus* is distributed widely throughout the region, except that in Namibia it has been reported only in the extreme northern region of the country. *Bulinus africanus* is generally restricted to eastern Africa. In the region under consideration here, *Bulinus africanus* is present only in eastern Zaire, which represents the most westerly portion of its range. Both *Bulinus globosus* and *Bulinus africanus* may act as intermediate hosts for *Schistosoma intercalatum* in eastern Zaire. *Bulinus truncatus* is not common south of the equator, being found only in the western coastal areas of the region, including Gabon, Congo Republic, Zaire and in Angola as far south as the Cuanza River in Luanda Province. North of the equator, its southern limits appear to be north of the Zaire River.

In Gabon, the intermediate host for *Schistosoma intercalatum* is *Bulinus forskalii*, which is distributed throughout the country.

Four intermediate hosts for *Schistosoma mansoni* occur in this region: *Biomphalaria pfeifferi*, *Biomphalaria camerunensis*, *Biomphalaria salinarium* and *Biomphalaria sudanica*. The distribution of *Biomphalaria camerunensis* in this region is in the southern end of the Central African Republic, south to approximately the northern border of Angola, and, in Zaire, encompassing the western drainage of the Zaire River and eastward at Banzyville and Kisangani. The range of *Biomphalaria salinarium* is restricted to northern Namibia and mid- to southeast Angola. *Biomphalaria pfeifferi* is distributed throughout the region, except in Namibia and southwest Angola. *Biomphalaria sudanica* is distributed in the southeastern Zaire River basin, this being the most westerly portion of the range of *Biomphalaria sudanica* in southern Africa.

Eastern and Southern Africa (including Uganda, Kenya, Tanzania, Rwanda, Burundi, Malawi, Zambia, Mozambique, Zimbabwe, Botswana, South Africa, Lesotho and Swaziland)

Five species of *Bulinus* which act as intermediate hosts for *Schistosoma haematobium* are found in this region. They are *Bulinus africanus*, *Bulinus globosus*, *Bulinus truncatus*, *Bulinus nasutus* and *Bulinus reticulatus*.

*Bulinus truncatus* is limited to few localities in eastern and southern Africa. It is present at a few places in Uganda, on the Kano plain and at Nyanza Province and Kito distinct, Kenya, Kigoma and near Mwanza, Tanzania, Karmga, Malawi, and the most southerly population was recently described from Blantyre, Malawi.

*Bulinus nasutus* has a limited distribution in eastern Africa. It is found in the regions surrounding Lake Victoria on the eastern shore. A second area of distribution of *Bulinus nasutus* is in the southeast coastal area of Kenya and the coastal regions of Tanzania south to Tuinduru and westward to Mbarali.

*Bulinus reticulatus* has a scattered distribution in a band running from Ethiopia to South Africa.

*Bulinus africanus* is widely distributed throughout all countries of eastern Africa, with a westerly distribution to exclude Botswana and mid- and western South Africa.

*Bulinus globosus* is also widespread and has approximately the same distribution as *Bulinus africanus*, except that *Bulinus globosus* is present in Botswana and does not reach as far south in South Africa as does *Bulinus africanus*. In South Africa, *Bulinus globosus* reaches only into the coastal plain of Natal and into the northern Transvaal. *Bulinus africanus* is primarily found in the highlands, *Bulinus globosus* at lower altitudes.

In eastern and southern Africa, six species of *Biomphalaria* which may serve as intermediate hosts for *Schistosoma mansoni* are present. These are *Biomphalaria pfeifferi*, *Biomphalaria choanomphala*, *Biomphalaria smithi*, *Biomphalaria stanleyi*, *Biomphalaria angulosa* and *Biomphalaria sudanica*. *Biomphalaria sudanica* is distributed from the Sudanese border southward in a belt through Uganda, through south-east Kenya at Lake Victoria (and east in Kenya at lakes Naivasha and Jipe), eastern Tanzania (and east in Tanzania at Arusha), into northern Zambia. It is not found south further than northern Zambia and it is absent from the eastern coastal plain of eastern and southern Africa.

*Biomphalaria pfeifferi* has a wide distribution throughout all countries of eastern Africa. It is not present in the coastal plain from Somalia to northern Mozambique. It reaches only to northern Botswana. In South Africa, it extends to northwestern Transvaal and southward in a narrow coastal zone to Port St. Johns. It is present in Swaziland, but not Lesotho.

*Biomphalaria choanomphala* is present in Lake Victoria, Lake Albert, Lake Kyoga and in the Nile rivers from lakes Victoria and Albert. *Biomphalaria smithi* is present in Lake Edward and Mirambi crater lake in Uganda.

Uganda. *Biomphalaria stanleyi* is present in Lake Albert and in Lake Tshohoha, Rwanda. *Biomphalaria angulosa* is present in the Kelenga swamp and Kelenga irrigation scheme, Lake Ngwasi, Little Ruoha swamp at Chambezi Wantipa and the Chozi River in Zambia and in swamps 40 miles north of Nkota Kota, Malawi.

## 6. Snail Intermediate Hosts of Human and Veterinary Parasites Other Than Schistosomes in Jordan

Snails of the genus *Lymnaea* constitute a threat to humans and domestic animals in Jordan. Two species, *Lymnaea natalensis* ("*Lymnaea auricularia*" in previous recent reports) and *Lymnaea truncatula* have been found in Jordan. The former snail was located in Azraq, in several sites close to the Yarmouk River (Akraba, Saham, Amrawa, Zeyzoun), in the Yarmouk River itself and in Ain Sheik Hussein in the Northern Jordan Valley. *Lymnaea truncatula* has a wider distribution and has been found in some 40 sites in the governorates of Irbid, Amman, Balqa, Karak and Maan (see Appendix H, p. 144).

*Lymnaea* snails are known as the intermediate hosts of *Fasciola* parasites, which are digenetic trematodes of animals of economic importance (sheep, goats, cattle, horses, etc.) and which occasionally infect man. The parasites live in the bile ducts in the liver of the mammalian hosts, causing damage to the liver (fibrosis) and sometimes premature death. In Jordan, *Lymnaea natalensis* is the common host for *Fasciola gigantica*, while *Lymnaea truncatula* is the normal host for *Fasciola hepatica*.

*Lymnaea natalensis* from Azraq has been found naturally infected with *Fasciola gigantica* larvae. Experimentally, the snail is highly susceptible to infection with the parasite. Adult flukes have also been recovered from cows and buffalos exclusively reared in Azraq. The prevalence rate was very high, reaching 100% in cattle older than three years of age. (For further details see Ismail et al. (1978), Saliba et al. (1977), Saliba & Othman (1980).)

*Lymnaea natalensis* from Azraq has also been found infected with several types of larval trematodes (longifurcate and brevifurcate cercariae, xiphidiocercariae and echinostome cercariae and metacercariae). The life cycles of these larval stages have not been studied, but it is expected that they infect several vertebrates in Azraq, including fishes, amphibians, reptiles, birds and mammals. The brevifurcate schistosome cercariae isolated from *Lymnaea natalensis* from Azraq are of specific importance. Exposure of mice to these cercariae produced male schistosomes (most probably of the genus *Ornithobilharzia*) in the hepatic portal veins of infected mice (Saliba, unpublished). Members of this genus are known to cause swimmer's itch (cercarial dermatitis) in humans and could infect mammals. One parasite, *Ornithobilharzia turkistanicum*, is known to infect domestic animals (cattle, sheep, goats) in different parts of Asia and utilizes *Lymnaea* snails as its intermediate

host. (For more details see Lutfy et al. (1978), Saliba (1977), Saliba & Othman (1980).) *Lymnaea natalensis* snails collected from sites other than Azraq did not shed cercariae at the time of collection, except for those snails which were collected in August 1983 from Ain Sheik Hussein. The latter shed xiphidiocercariae.

*Lymnaea truncatula*, the normal intermediate host for *Fasciola hepatica*, is more abundant than *Lymnaea natalensis* in Jordan. Although snails collected were not shedding cercariae at the time of examination, it is expected that in many parts of the country the snail plays a role in infecting animals grazing or drinking along some of the waterbodies where the snail is found. Sheep and goats have been found infected with *Fasciola hepatica* in Jordan and undoubtedly *Lymnaea truncatula* was involved in the life cycle of the parasite. This snail is difficult to maintain in the laboratory long enough for the parasite to develop and cercariae to be shed in water in case the snails were infected.

*Planorbis planorbis* snails have been found in Azraq oasis, but only in few numbers. No parasites were recovered from the specimens collected. Furthermore, experimental studies on the potential of this snail to become infected with miracidia of *Schistosoma mansoni* from Egypt showed that the snails were refractory to infection.

## 7. Ecology of Freshwater Snails in Jordan

### Ecological Aspects of Snail-Mediated Diseases

Schistosomiasis has been called an ecological disease. The successful transmission of the schistosome parasite requires ecological interaction between the causative trematode worm, the snail intermediate host and the human definitive host. Consideration of the transmission cycle from this perspective provides a greater understanding of the dynamic relationship between the physical aspects of the environment and the biomedical components (that is, humans and snails) of the disease cycle.

The modern scientific definition of the term "ecology" denotes a study of all factors which determine the distribution, abundance, success and influence of the particular species in the environment. An ecological investigation of any parasitic disease must include studies of the biology of both the parasite and its various hosts for the purpose of assessing possibilities of control of human infection by intervention at critical points in the epidemiological cycle. Ecological studies must consider a wide range of factors, including the important physical environmental influences (the so-called abiotic components), the biological characteristics of the particular species being studied (these include habitat selection, behavior, population dynamics, individual growth rates, etc.) and the interactions of the biological community of other species.

The epidemiologies of parasitic diseases are closely related to the local ecology of the transmission sites. The host-parasite relationships of the molluscan-borne human diseases are thus intimately tied to the immediate aquatic ecology.

### Jordanian Aquatic Ecology

The ecology of Jordan is very complex and presents a wide range of local habitats (see pp. 167-181). Located along the northern expanse of the Great African Rift system and influenced by the climatic conditions associated with the eastern Mediterranean weather patterns, as well as those of the arid Arabian desert, the combination of topography and climate combine to produce a great variety of habitats. Desert, steppe and Mediterranean regions are similar to those of nearby countries, but the Jordan River Valley presents a unique set of geological, climatic and hydrological conditions found nowhere else on earth.



The naturally formed water habitats in Jordan are a result of the local topography, soil types and climate; these waterbodies may be permanent types or they may be seasonal or ephemeral. The permanent waterbodies are such standing bodies as the pools of Azraq, which cover a large area and support a complex oasis type flora and a rich fauna. Scates (1968) reported over 200 species of birds and nine species of mollusks recorded from the diverse set of wetlands, spring pools, streams and lakes which cover about 26 square kilometers. We found these nine species, plus additional ones. Other permanent natural waters include dispersed spring pools of generally small sizes. Human settlements are usually associated with these small permanent spring pools. A small rock impoundment of spring water at Disi near Wadi Rum is an example of an isolated permanent spring pool. Other nonpermanent springs and spring pools are common in such areas as the northern reaches of the Jordan Valley where groundwaters emerge from the porous calcareous bedrock as seeps or springs. These sources are subject to local groundwater alterations over time and may become depleted or shift sites of emergence over the decades.

Swamp habitats have been formed in the flood plains of the Jordan River and on the margins of the Dead Sea and the pools of Azraq. These swamps are characterized by emergent aquatic reeds, and in some areas close to the Jordan River they are vegetated by strands of *Tamarix* trees.

The flowing waters may similarly be permanent or temporal. The upper reaches of drainage basins may only support temporary waterways which carry off surface water derived from rain or snow. These intermittent streams occupy the upper parts of wadis, which have become steeply eroded by the surface runoff. The larger temporal streams, formed by the confluence of many smaller wadi streams, are also temporal, but may harbor stream pools for some time after the rains have passed. Permanent streams are developed when the wadis have eroded down to the level of groundwater deposits or where underground aquifers emerge to provide a steady discharge. Such features may be seen in many of the larger stream systems.

The principle river flows are irregular and all are discharged to the Dead Sea. In the north, all rivers descend to the Jordan Valley, which intercepts drainage of the river systems and gives rise to the Jordan River, the only river on earth to flow its entire length below sea level. It arises from Lake Tiberias (in Palestine) 64 meters below sea level, and empties into the Dead Sea, a hypersaline evaporation basin 292 meters

below sea level. The Dead Sea has salinities of 226,000 parts per million and can support only a very limited number of salt-tolerant bacterial and invertebrate species.

### Jordan's Changing Water Resources

In the Kingdom of Jordan, the ecological conditions which influence the distribution of *Bulinus truncatus*, the snail intermediate host of the causative agent (*Schistosoma haematobium*) of urinary schistosomiasis, have undergone rapid and significant change. National needs for increased storage of irrigation water, flood control, wastewater management and increased demands for municipal and industrial water supplies have resulted in major hydrological development schemes which have drastically altered the country's historical surface water flow patterns. These alterations include such engineered projects as the construction of dams, the building of pools and reservoirs, the drilling of artesian wells and construction of water redistribution schemes. Redistribution systems include the range of activities from small village drinking water piping projects to massive scale pumping schemes such as the Deir Alla-Amman pumping project.

Agricultural water uses result in habitat alterations. Irrigation canal systems may be quite complex and consist of large, high-volume primary canals and successively smaller, but more numerous, secondary, tertiary and quaternary distribution canal systems which deliver irrigation water to the fields. Drainage canals are employed to remove excess ground water from areas saturated by irrigation or surfacial water (swamps and marshes are similarly drained for conversion to agriculture). Fish ponds are used to culture some introduced fishes for protein production. These ponds, which are not common on the East Bank at this time, have proved to be areas of snail culture as well as areas of fish production. Fish farms on adjacent lands of the West Bank in the northern Jordan Valley inadvertently support scores of *Bulinus* breeding foci.

Quarry pits for the mining of gravel or minerals may also create new conditions capable of being colonized by the intermediate host snail. Such sites are present in the Jordan River flood plain and in other regions of the country. Saliba et al. (1980) cited the previous lack of the snail intermediate host as a key factor in the absence of indigenous cases of the disease in the country. The local ecology has become a critically important element in the proliferation of potential snail hosts in the area.

The naturally occurring environmental conditions formerly imposed strict constraints upon the distribution of aquatic organisms found in Jordan. The major rivers tributary to the Jordan, which include the Yarmuk, Ziglab, Zarka and Shaeib drainages, were formerly intermittent streams which carried only seasonal runoff from the eastern plateau down steep, deeply eroded wadis to the Ghor. This seasonal and uncontrolled runoff presumably prevented establishment of permanent populations of snail intermediate hosts on the plateau or in the Ghor. Similarly, east of the Dead Sea, there are a series of westwardly draining wadis which discharge directly into the Dead Sea at various points. Wadi Mujiib, Wadi Karak and Wadi Husa are intermittent stream courses, whereas Wadi Ma'in carries a more regular flow of spring-derived ground water as well as the rain or snow surfacial runoff. South of the Dead Sea, Wadi Araba flows intermittently over a northerly course. As these rivers enter the Dead Sea, any aquatic life which may have been transported is killed by the high concentration of brine. Thus, in the past a combination of limited rainfall, intense runoff, sparsity of permanent bodies of standing water, great expanses between waterbodies and the sterilizing effects of the Dead Sea as a receiving body resulted in ecological conditions which were too severe to allow the successful establishment of medically important snail species.

Extensive recent changes in water storage and distribution have stabilized many water sources and have transformed environments from semi-arid biotopes to perennial aquatic habitats. Technological advances of the last decades have allowed construction of the Zeglab Dam, the East Ghor Canal and its extensions (with their associated distribution systems), and the building of the King Talal Dam. These needed resources have had great national significance and have greatly improved agricultural productivity throughout the valley, just as improvements in municipal water systems and wastewater treatment plants have brought urban improvements. But, these projects have also created new perennial habitats favorable for breeding and further distribution of snail intermediate hosts.

#### Distribution of Bulinine Intermediate Host Snails in Nearby Countries

The genus *Bulinus* has been recorded throughout much of North Africa, parts of the eastern Mediterranean and the Arabian Peninsula. Urinary schistosomiasis is a common public health problem in most

areas in the region. The Sudan, Egypt, Saudi Arabia, North Yemen, South Yemen, Lebanon, Syria and Palestine all have reported problems with disease transmission due to the presence of snail intermediate hosts and infected humans. Arfaa (1976) reported snail hosts breeding in the waters of the Saudi Arabian villages of Tayama and Tabuk in Medina Province close to the Jordanian border. Baguir (1975) reported studies on the schistosomiasis problem in Iraq and Watson (1958) cited the occurrence of the snail intermediate host in the southern part of the Litani River system in Lebanon. Kigundu Githaiga (1976) reported snail intermediate hosts from the northern provinces of Syria. Hulse (1971) presented evidence that the ancient city of Jericho in Palestine was an active transmission focus in the Bronze Age over 2,600 years ago. Witenberg & Saliternik (1957) listed 84 breeding sites in various waterbodies west of the Jordan River. Of these sites, many were within a few kilometers of the Jordan River, and one site, described as an area of highest breeding intensity, is located near Beit Shan, only a few kilometers from Sheik Hussain.

It is noteworthy that many of the above authors commented on the lack of temporal stability of the snail populations surveyed. The snail populations undergo periodic shifts in both abundance and distribution, and appear to be quite variable, both seasonally and from year to year. Watson (1958) observed great seasonal variation between population numbers in Iraq and Egypt, but was unable to clarify the reasons for differences in the times of population maxima observed between the two regions. It is obvious that seasonal factors influence the breeding status of snail populations, but the effects of more unpredictable climatic influences, such as droughts or excessive rain or snow, on population dynamics have not been studied in sufficient cases to allow conclusions to be drawn. Chu et al. (1968) monitored a total of 3,130 *Bulinus truncatus* habitats in Khuzestan, Iran, during the period of 1963-1965. They reported that over the period, 41 known habitats underwent local spontaneous extinction and 78 new habitats appeared. The inability to anticipate shifts in distribution and population density must be interpreted as a mandate for maintaining the highest degree of vigilance by those groups charged with the duties of snail surveillance.

It is obvious that Jordan alone has been insular in the region with respect to the previous exclusion of the genus *Bulinus*. The most tenable reasons for this were that the former lack of suitable habitats, the sparsity of permanent water basins and the relatively great distances which intervened between the permanent springs, reservoirs, cisterns

and streams were inimical to the successful establishment of breeding colonies. More limited passive transport opportunities for dispersal also may have contributed to the absence of *Bulinus* in Jordan.

#### Influence of Physical Factors on Snail Distribution

*Bulinus truncatus*, a planorbid pulmonate snail presumably derived from temperate ancestors and various descendants, has successfully invaded semi-tropical and tropical environments. Burch & Natarajan (1966) remarked that the genus *Bulinus* is distributed over most of the African continent where habitats are suitable for pulmonate snails. The northern species, *Bulinus truncatus*, extends southward to the equatorial regions of Cameroon, Gambia and Gabon. In the Near East, the species extends to northern Iraq, near the Turkish frontier, and occurs in Iran, thus providing a north-south range of approximately 37 degrees of latitude. It may be inferred from this range of distribution that the species exhibits a wide range of tolerance of physical and chemical conditions. Abdel-Malek (1958) cited occurrences of *Bulinus* in the highlands of Ethiopia and Yemen at altitudes in excess of 2,200 meters (Jordan's highest elevation is below this at 1,736 meters). Thus, elevation gradients *per se* offer no limits to the distribution of snails in the country.

#### Temperature

Temperature is an important physical factor which may influence the local and seasonal presence of *Bulinus* in various habitats. Although temperature is not a primary limiting factor in most areas of Jordan, occasional thermal springs, which emit ground water at temperatures of up to 90°C, may exclude snails for some distance from the thermal source. The springs at Zarka Ma'in and Hamma Ma'in, upon first emergence, are of excessive temperatures to support breeding snail intermediate hosts. Temperatures in excess of 40°C have been reported to cause significant mortalities in *Bulinus truncatus* (Watson, 1958). These springs should not be overlooked as potential habitats, since they may provide suitable temperatures in cooler, downstream reaches of their flows. Such a situation is found in the lower reaches of the Ein Nimreh Springs, where a few meters from the source the warm effluent maintains temperatures close to the breeding optimum throughout the winter months. Many earlier reports cite breeding temperature minima as 18-22°C for Egyptian and Sudanese races of *Bulinus truncatus*, but Watson

(1958) cited evidence of Iraqi snails breeding at temperatures as low as 11°C. A similar condition has been observed in the upper reaches of the Zarka River, where teams from the University of Jordan and the Ministry of Health have found actively reproducing *Bulinus* at temperatures of 12°C. The northern populations appear to have much lower breeding minima than do the more extensively studied African populations. These Near Eastern populations also maintain general activity over a greater range of temperatures and have been observed in waterbodies which had a thin layer of ice in winter. Thus, it appears that in most cases temperature is not a constraint to the further spread of the species to new habitats in Jordan, although temperature relations may affect the intensity of breeding in established sites. Other areas have reported significant thermal effects on seasonal population dynamics. Generally, a peak in breeding activity is observed in early summer as temperatures begin to increase; a second peak is observed again in the fall as temperatures begin to decline from summer maxima. Watson (1958) observed such seasonal variation in the Iraqi snails and Saliba et al. (personal communication) have observed similar peaks in breeding activity of the King Talal Dam population. The thermal influences on breeding may act together with other seasonal variables such as length of day, seasonal fluctuations in water level and seasonal variations in growth of algae to exert a combined influence on breeding.

#### Water Velocity

Water velocity is another important variable influencing snail distributions. Habitat selections relative to water currents have been investigated by several authors. The existing literature does not accurately define the range of current tolerances exhibited by the Jordanian snail intermediate host species. Witenberg & Saliternik (1957) studied *Bulinus truncatus* in the region west of the Jordan River and concluded that the species there lives only in stagnant or slowly flowing water. Their statement that "a velocity of over 20 cm per second is unfavorable" should be interpreted with caution for *Bulinus* elsewhere. Abdel-Malek (1958) stated that water current in *Bulinus* habitats is not strong and normally host snails are not found at falls, in torrential rivers or on the exposed banks of large lakes. We have collected thousands of *Bulinus* specimens from the sandstone-littered banks of the Aswan High Dam Lake in Egypt. Similarly, the limestone headwall of the King Talal Dam reservoir offers a very productive habitat for the breeding of *Bulinus truncatus*. The undersides of small rocks and cobblestones offer

sufficient protection from wave action and predators to sustain sizable snail colonies.

Stream velocities may inhibit successful colonization by these benthic snails, but, again, caution is urged in interpreting the literature. Appleton & Stiles (1976) observed that water velocity is a critical factor in determining the suitability of habitats, with the maximum tolerable velocity for host snails being about 30 cm per second. The University of Jordan snail survey team found a possible exception to this general rule in the Zarka River about 5 km west of Ein Nimreh. At this *Bulinus* focus, the surface current was measured at 78 cm/sec and several specimens were collected from the center of the stream at an average depth of 20 cm. This site also confirmed the presence of egg masses adhering to the stones on the bottom of the stream in mid-January. (These snails were reproductively active under the severe conditions of both temperature and velocity.) It must be realized that moving water may flow in either a turbulent or laminar condition. Irregular stream beds, paved with stones, create current gradients of decreased velocity toward the bottom and the shores. The velocity of flow rapidly decreases toward the bottom to create a boundary layer of very sharp decrease in current velocity, which approaches zero at a distance of a few millimeters from the substratum. The rough bottom also creates alterations in the direction of current, called eddies, which provide refuge from the powerful flows above, allowing bottom-dwelling organisms to become established. Only when the force of the current becomes so intense as to dislocate the rock substratum will the bottom community become dislodged. These torrential conditions may decimate populations in their breeding sites in rivers, but they may also serve to transport snails to new downstream sites where they can become established as the flood subsides. Thus, intense rains may act as agents of redistribution of host snails.

High velocities in smooth, concrete-lined canals may limit the snail's ability to hold against the current. Velocities in excess of 0.3 meters per second can prevent the establishment of colonies since the boundary layer of low velocity may be too close to the substratum to allow the snails to hold. However, unused canals may have residual pockets of standing water in depressions and should not be overlooked in surveillance efforts. Storage cisterns used for providing irrigation water on days when canal service is interrupted may also provide suitable shelter for breeding colonies.

### Substratum

Substratum, or bottom type, is another factor influencing snail habitat suitability. Naturally occurring substratum types range from rock to silt and to plant surfaces. Artificial substrata include all artificially produced surfaces and range from concrete to discarded plastic greenhouse sheeting and household debris. Generally, snails will frequent most substratum types except sand that is subject to shifting by currents. The host snails have been observed to lay eggs on most firm, stable surfaces, although in large ponds or reservoirs they tend to avoid laying eggs on exposed or horizontal faces where the eggs would be exposed to predation or grazing. Underwater leaf litter provides an excellent egg deposition surface, as does almost any submerged object, such as sticks, abandoned tires, shoes, discarded greenhouse plastic sheeting, etc. The availability of a suitable substratum may be a determining factor influencing the output of a breeding colony. Eggs may be deposited upon floating debris, only to be passively transported to new locations by rafting of the debris to new localities by wind or water currents. The substratum is also important as a source of nutrients to newly hatched snails. The offspring feed on microscopic bacteria and algae which form coatings on the submerged objects. Concrete-lined cisterns may also provide good habitat in the absence of fish, crabs or other potential predators. We have recovered scores of host snail specimens from the open concrete holding tank of the Abu Simbel drinking-water treatment plant in Egypt. Thus, no substrate type can be overlooked as a potential breeding site.

### Changing Water Levels

Fluctuations in water levels can affect populations of host snails in various ways. Sudden increases in water level can expose new breeding areas and stimulate reproduction. Laboratory studies have demonstrated increased egg output in populations presented with fresh egg deposition surfaces. Although this response has not been documented in the field, indirect evidence of the effect is provided by reports of intense breeding activity associated with rising water levels after the onset of the rains. Cridland (1957) observed a ten-fold increase in the population of young *Bulinus forskalii* in a permanent pond in Uganda after the onset of the April rains.

Snail intermediate hosts have the ability to estivate when confronted with dropping water levels and drying conditions. Adult snails can burrow into soft substratum and suspend metabolic activity for periods of



several months. Upon the return of favorable conditions, the snails can become active within minutes of rehydration and can lay viable eggs within hours of reemergence. Experiments conducted at the University of Jordan snail laboratory have shown survival rates of estivating snails to be in excess of 90%, with a burst of egg laying following within 12 hours of emergence. Thus, alterations of water level cannot be viewed in all situations as effective controls of population, but must be viewed with caution as possible mechanisms for affecting the biodynamic status and distribution opportunities of the host snail populations.

#### Influences of Chemical Factors on Snail Distribution

Numerous studies have addressed the effects of dissolved chemicals in the aquatic environment on limiting the distributions of snail populations. Macan (1963) attempted to correlate snail distributions in the British Isles with the chemical characteristics of the water, but found no consistent results. Appleton (1978) reviewed abiotic factors influencing host snails and concluded that water quality within the normally encountered range does not influence snail distribution patterns significantly, but may determine their local abundance.

Only in extreme circumstances will the chemistry of natural waters be responsible for the exclusion of snail species. The chemistry of Jordan's waters has been analyzed for this purpose and all but a few aquatic habitats have been found appropriate for the existence of schistosome host snails. The Dead Sea is obviously fatal to all but extremely hardy arthropods. Of the other hundreds of habitats visited, only three were found to offer such extreme chemical environments as to eliminate them as habitable by host snails. High levels of sulfate and copper were tentatively indicated as limiting to snails in those localities. All other sites investigated proved to be suitable.

#### Breeding Potential of Snail Intermediate Hosts

*Bulinus truncatus* and other host snails are exceptional in their abilities to produce offspring; their intrinsic rate of natural increase is very high and, once a population becomes established in an area, it has the capacity to increase by up to 95% per week. Dazo et al. (1966) determined the intrinsic rate of increase of the Nile Delta population of *Bulinus truncatus* in the field to be at a very high level. As these snails are functionally hermaphroditic, a single adult, in the absence of a suitable mating partner, can self-fertilize and become the progenitor of an

entire breeding colony. In this manner, a single snail or egg mass, accidentally transported and introduced into a new habitat, can result in a significant extension of the range of the species. The small individual size of the organism facilitates such dispersal into new areas. Young snails, less than a millimeter in size, may be transported by migratory waterfowl, or they may be contained in the water-transport vessels of travellers, or even in the mud adhering to the feet of domesticated animals. Once a breeding population is established at a site, it may then act as an additional center of dispersal to other outlying areas. Even if a breeding focus is treated by control measures, it must be continually monitored to avoid problems of resurgence from surviving snails or re-introductions of snails by the original transport mechanisms.

Control of host snail populations has proven difficult because of the prolific reproductive output of the mature snails. Schistosome intermediate hosts have survived and flourished in the most marginal habitats due to impressive reproductive efforts of the species. Ecologically, snails such as *Bulinus truncatus* can be regarded as "pioneer" species because of their ability to translocate to newly created or newly altered areas and become rapidly and successfully established. Frequently, these snails are among the first to inhabit new man-made environments and are the most adapted to recolonize treated foci. The small mollusks are a formidable challenge to the best public health efforts of afflicted countries.

#### The Potential for Establishment and Spread of Snail Intermediate Hosts in Jordan

A snail survey of the Near East, conducted in 1950 and 1951, addressed the status of Jordan relative to possible indigenous populations of *Bulinus*. Abdel Azim & Gismann (1956) reported the finding of no host snails after a very limited survey of the Zarka River, the Jordan River Valley and the North Shounah region. A second survey was reported by Chu (1969), with negative results.

The presence of the snail host of urinary schistosomiasis has been recorded in Jordan for less than 10 years. In 1975, the first confirmed presence of this snail was reported from a small, open, concrete storage cistern near the East Ghor Canal in the Muthalath Al-Masri area of the Jordan Valley (Saliba et al., 1976). The origin and the mechanism of dispersal are still speculative, but several hypotheses are possible. The small dimensions and vertical walls of the cistern would seem to preclude all but human activities as possible distribution agents. The concrete

cistern is isolated from all naturally flowing waters, but could be filled from water transported by the East Ghor Canal. It also could have received quantities of water from large military water-transport vehicles originating in nearby friendly countries. Other unknown mechanisms may have been responsible for the introduction, but the origin of the snails will never be determined with certainty. After the discovery and eradication of the population, an intensified snail survey program was launched throughout the country. The World Health Organization sponsored a limited field visit which again failed to locate the presence of host snails, but advised of the serious nature of the situation (Rey, 1977). A joint team from the University of Lowell, NAMRU-3, and the University of Michigan conducted preliminary surveys with the University of Jordan and the Jordanian Ministry of Health in 1978. The findings of the group were again negative, but the serious nature of the threat of schistosomiasis to Jordan was restated.

A second focus was reported by Saliba & Salameh (1981) in the historic Roman pools of Jerash. These pools seasonally drain into Wadi Jerash and ultimately into the Zarka River and the King Talal Dam impoundment. The Roman pools, like the cistern at Muthalath Al-Masri, are a relatively small man-made environment; but, unlike the original focus, the pools could more readily be visited by birds or other non-human agents of dispersal. The Roman pools, unlike the concrete cistern, have a more complex habitat structure: a mud bottom supporting a quantity of rooted aquatic vegetation which harbored *Bulinus*. This habitat was treated by mollusciciding and habitat alteration, which involved removal of the silt substratum and elimination of the aquatic macroflora.

In 1980, a joint team formed by the University of Jordan and the Jordanian Ministry of Health instituted a systematic snail survey of the country. Shortly thereafter, the host snails were discovered in the reservoir of the newly filled King Talal Dam. These snails were found on the plentiful flotsam of driftwood and other debris. Intensive surveys in the Jordan Valley over the period from 1980 to 1983 resulted in the discovery of six new sites where snails were collected from springs, spring ponds and drainage canals. Two additional sites showed quantities of dead shells, but no live snails. The two extinct sites were of recent origin and thus indicated the abilities of the sites to become well established, only to become extinct.

In 1982, snails were recovered from the Zarka River about 17 kilometers upstream from the King Talal Dam. The furthest extent of

colonization of the river was located at Ein Nimreh, a set of warm springs in the Zarka Valley. Subsequent searches of the river revealed extensive populations along the length of the upper Zarka River from Ein Nimreh to the reservoir. In 1983, the snails were found at a few sites along the Zarka River below the dam as the river descends into the Ghor.

The mollusk control teams of the Ministry of Health are continuing to monitor the aquatic habitats of the region. However, many new habitats are being created as a result of various private and government-sponsored projects and many old habitats are being modified, frequently creating circumstances more favorable to the host snail species.

In 1983, breeding foci were located within the Kafreem Dam reservoir and along the Yarmuk River in the northern part of the Ghor.

The potential for further dissemination of the host snail species in Jordan is alarming. Within the past decade the discovery of new foci increased at a logarithmic rate. This increase is not believed to be related simply to increased survey activities in locating previously undiscovered breeding habitats. Jordan is in the midst of a veritable population burst of the opportune snail species. The strain of *Bulinus truncatus* populating the area is well adapted to the severe environmental challenges offered by Jordan's complex ecology. The Jordanian snails do not conform to the strict environmental limitations which previous authors have described for the African *Bulinus* species group. The apparent heartiness of the local race is responsible for an extended breeding season and the ability to breed in swifter water than is recorded from other localities. The rapid proliferation of newly created habitats has allowed the dispersal mechanisms to become more effective, and the increases in potential dispersal opportunities have further magnified the problem. Passive transport by migrating animals, human travellers and especially the transport of great volumes of water by hydrologic development have presented dispersal avenues unlike anything previously seen in the history of the country. Jordan has undergone such change in the past decade as to increase agricultural production by several orders of magnitude. The increase in permanently available water from governmental and private-development projects has transformed the country into a prime site for establishment of the disease on a large scale.

An additional cause for alarm is the inability of the control efforts to eradicate the snails from certain waterbodies, including the Zarka River and the King Talal dam impoundment. Very few control efforts around the world have resulted in the permanent elimination of snails from foci. The biodynamics of *Bulinus truncatus*, in particular, present difficult

challenges to public health authorities at all levels and Jordan is no exception to this problem. New and vigorous strategies must be applied to specific problem habitats. Each focus must be evaluated from an ecological perspective and particular site-specific measures must be implemented. Consideration must be extended to all types of control, including habitat alteration, temporal variations in water level and velocity, use of biological competitors and *a priori* design modifications of planned projects to diminish potential spread of the snail problem.

Control, surveillance and survey personnel must be alerted to the additional hazard of introduction of the snail hosts (members of the genus *Biomphalaria*) of the intestinal schistosome, *Schistosoma mansoni*. Species of this snail genus have been recorded from neighboring countries and the increased ease of travel to and from these countries presents an imminent threat to Jordan.

## 8. Snail Control

In considering the various methods of snail control as another important phase of a National Bilharziasis Program, it is necessary to define what is meant by the term *snail control*. It needs to be clarified from the onset that control is not synonymous with eradication.

The objectives of snail control are to limit the spread of infection, reduce morbidity or parasite transmission to a level of prevalence where it is no longer considered a public health problem. This requires an ongoing program with consistent recurrent efforts, especially as regards the application of molluscicides at potential parasite transmission sites. In terms of snail control, the different methods of control include: (1) altering environmental conditions under which the snails live, (2) application of a molluscicide, and (3) biological control. A prerequisite for any snail control program also involves detailed snail surveys.

### Chemical Control

Various schistosomiasis control projects conducted in Egypt, Brazil, Ghana, Philippines, Venezuela, Madagascar, Tanzania, St. Lucia and elsewhere have shown that snail control by use of molluscicides, either alone or in combination with other methods (chemotherapy, environmental measures, health education and community participation among others), can result in considerable reduction and/or elimination of transmission. Molluscicides are, therefore, recommended as one of the methods of choice for the control of snail intermediate hosts of human schistosomes. The guidelines, as published by the World Health Organization in 1965, for the screening and evaluation of molluscicides are recommended for use in this regard. The data from the studies in various countries show that the use of molluscicides is very cost-effective where the volume of water to be treated per person at risk is small. Mollusciciding is also well suited to relatively arid areas where transmission sites are small and seasonal. In the case of large rivers, lakes and dams, mollusciciding may not be as feasible or cost-effective unless transmission is focal and the snail hosts are not distributed throughout these water systems. Generally, area-wide mollusciciding can, however, be cost-effective in some large irrigation schemes, where human population density is high and where good water-management procedures are practiced.

Molluscicide compounds which deserve mentioning are listed in Table 5. Recent trends in molluscicide usage have been towards improved

cost-effectiveness and reduction in environmental damage. Efforts in this direction are being made through new or improved-delivery systems and the development of more target-specific compounds.

A review of the current literature concerning available and candidate molluscicides indicates that, with the exception of the nicotinilide group of compounds, there are no new compounds to be added to the list of molluscicides presented in the report of the World Health Organization's Expert Committee on Schistosomiasis Control.

Two compounds that are of major interest are niclosamide and trifenmorph. Niclosamide is now more widely used than trifenmorph. Trifenmorph, despite its high efficacy, even at very low concentrations, is no longer readily available and thus its use is diminishing.

When feasible, it is suggested that the local manufacture of molluscicides be explored. This approach may not only stimulate the development of a local industry, but may reduce inherent difficulties encountered in transport and importation. In Egypt, for example, the production of 2,5-dichlor-4'-nitrosalicylanilide started as a result of such an approach.

Other molluscicides include copper compounds, organotins and nicotinilide. One advantage of the use of copper salts is that they are readily available and have a large data base on their use in snail control. The use of organotins, especially bis-(tributyltin)-oxide, as molluscicides is not recommended because of long-term cumulative effects on aquatic life forms. Nicotinilide and its 3'- and 4'-chloroanalogues have been shown to be effective against freshwater snails when used at concentrations of 0.2 mg/l. Only limited activity has been demonstrated against snail egg masses. No toxicity was found among fish, tadpoles, frogs and water plants when dosages of 2-5 mg/l of each of the three compounds were applied to fish ponds. Toxic activity was not demonstrated against goldfish or *Daphnia* sp. at concentrations lethal to snails.

Mice tolerate dosages of nicotinilide and its 3'- and 4'-chloroanalogues as high as 2 g/kg body weight, while rabbits showed very minimal toxicity for ear and eye irritation tests. No toxicity was observed when third-instar larvae of *Aedes aegypti* were exposed for 24 hours to concentrations of 4'-chloronicotinilide at 5 mg/l. The 4'-chloronicotinilide analog has a half-life of approximately 10 days. Development of these compounds in slow-release formulations is continuing. Methodology is being developed for analysis of various concentrations of these compounds in water, as well as for appropriate routes for commercial synthesis.

TABLE 5. Properties of some molluscicides.\*

	Niclosamide	Trifenmorph	Sodium pentachlorophenate	Copper sulfate	Nicotinanilide (candidate compound)
Physical properties					
Form of technical material	crystalline solid	crystalline solid	crystalline solid	crystalline solid	crystalline solid
Solubility in water	230 mg/l (pH dependent)	0.02 mg/l	330 g/l	316 g/l	not known
Toxicity					
Snail, LC <sub>90</sub> (mg/l x h) <sup>1</sup>	3-8	0.5-4	20-100	20-100	5
Snail eggs, LC <sub>90</sub> (mg/l x h) <sup>1</sup>	2-4	240	3-30	50-100	20-50
Cercaria, LC <sub>90</sub> (mg/l)	0.3	no effect	not known	no effect at molluscicidal concentrations	not known
Fish, LC <sub>90</sub> (mg/l)	0.05-0.3 (LC <sub>50</sub> )	2-4	not known	toxic <sup>2</sup>	>30
Rats, LD <sub>50</sub> (mg/kg given orally)	>5000	1400	40-250	300	>2000 (mice)
Herbicidal activity	none	none	phytotoxic	phytotoxic	unknown



TABLE 5. (Continued.)

Formulations	700 g/kg wettable powder 250 ml/l emulsion concentrate	165 ml/l emulsion concentrate 40 g/kg granules	750 g/kg flakes 800 g/kg pellets 800 g/kg briquettes	980 g/kg pentahydrate crystals	not yet formulated
Field dosage					
Aquatic snails (mg/l x h) <sup>1</sup>	4-8	1-2	50-80	20-30	not known
Amphibious snails (g/m <sup>2</sup> )	0.2	ineffective	0.4-10	ineffective	not known

\*From *Epidemiology and control of schistosomiasis*, Technical Report No. 643, World Health Organization, Geneva, 1980.

<sup>1</sup>The term "mg/l x h" indicates that the figures given are the product of the concentration and the number of hours of exposure.

<sup>2</sup>Toxicity depends very much on the species of fish and on the water quality.

### Molluscicides of Plant Origin

Endod, extracted from the plant *Phytolacca dodencandra*, has been studied extensively for use as a molluscicide of plant origin. Endod is a saponin and is not target-specific and is somewhat less cost-effective than the synthetic chemical molluscicide, niclosamide. If proven to be safe and effective as a molluscicide, endod could be produced locally and very easily since it does not require a complicated extraction procedure. The potential toxicity of endod still needs clarification. Availability of this material for widespread use as a molluscicide would depend on commercial growing or well-organized harvesting programs at the local level which has not been attempted thus far. There are a number of other plant substances listed in the literature which deserve study as potential molluscicides.

### Focal and Area-Wide Application of Molluscicides

This approach is associated with the identification of foci and seasonal transmission patterns. It can be used under many endemic conditions as well as in large impounded water schemes and is very cost-effective. It should be pointed out that the use of this procedure may depend on the type of surveillance program in operation. Such conditions as high population densities in extremely large irrigation areas where human-water contact patterns are diffuse may not allow the use of focal molluscicide application. Under such conditions, area-wide mollusciciding may offer the most cost-effective approach, coupled, of course, with good water-management procedures.

### Chemical Control in Jordan

Of the available molluscicides, niclosamide (5,2-dichloro-4 nitro-salicylic-anilide) has been used in Jordan. This molluscicide comes as a 70% water-dispersible powder which is bright yellow in color. This chemical compound not only kills snails, but is detrimental to snail eggs and parasite cercariae as well, while it is non-toxic to humans and does not affect vegetation. In laboratory studies in Jordan on the effect of niclosamide on *Bulinus truncatus* snails, 0.3 mg/l of niclosamide produced 100% mortality (Saliba, 1984).

When the National Control Programme was implemented, the following mollusciciding method was used. The volume of water in potential

transmission sites was measured in cubic meters (surface area x average water depth =  $m^3$ ) to determine the amount of niclosamide required. The niclosamide was mixed with water (1-2 ppm) and sprayed along the water's edge until the required quantity was applied. For large water sources, the above formula, which includes depth, cannot be applied because of the great expense of the chemical and, besides, the snails only live on substrata and in the upper 2 meters of water. In such large waterbodies (for example, the King Talal Dam; Fig. 53), only focal treatment by spraying around the water's edge was undertaken. This focal spraying has been repeated at regular intervals every 3-4 months. For other smaller infested water sites, reapplication has been repeated every 4-6 months. It is necessary to re-survey treated water at regular intervals to determine the frequency of application.



FIG. 53. Applying molluscicide (niclosamide) at the King Talal Dam.

### Environmental Control

The effects of environmental control are longer lasting than mollusciciding, but entails more labor. Certain physical changes will make natural habitats less suitable for snails. Some feasible possibilities include increasing the flow of water, draining or filling-in small heavily

infested water sites (borrow pits, temporary ponds and swamp areas), clearing terrestrial and aquatic vegetation, and preventing further pollution of water sources. Snail intermediate hosts, in general, prefer gently flowing, slightly polluted water and flourish in standing pools which have favorable conditions for food, shelter and oviposition. It is in such habitats that the environment can be altered. Clearing vegetation, particularly weeds, which provide egg-laying sites and food surfaces for snails, has the double effect of destroying the snails' ecological niche as well as causing water velocities to increase, both of which discourage snail reinvasion. Drainage and the filling-in of infested sites desiccates the habitat, but these conditions must be maintained: a low percentage of the snail population can withstand desiccation by aestivating, thereby readily repopulating the habitat within a short period due to the snails' prolific fecundity. Achieving results by this method will most likely involve bulldozing.

### Biological Control

Since it is necessary for the *Schistosoma mansoni* and *Schistosoma haematobium* parasites to penetrate and infect a snail intermediate host during their life cycles, it is theoretically possible to control schistosomiasis by eliminating the snails that the parasites infect. One of the many methods devised to attempt to eliminate or control the snail intermediate hosts of schistosomes is biological control. Biological control involves the use of one organism to control the population of a second organism. Theoretically, biological control of a snail species is specific for that species, meaning that only the species to be controlled is harmed, while other organisms which live in the same habitat are not harmed. The most widely studied methods of biological control focus upon control of the desired species by 1) predation, parasitism or pathogenic organisms, 2) larval antagonism or predation by other trematode parasites, and 3) competition between other species of molluscs and the intermediate hosts.

Many organisms which are natural predators or parasites of snails have been described which may have some potential as biological control agents against schistosome intermediate host snails. These include other trematode parasites, marsh flies (Sciomyzidae), crayfish, ostracods, aquatic insects, leeches, nematodes, protozoans, pathogenic bacteria and even a species of carnivorous plant.

The potential role of most of the organisms listed above in biological

control has not been determined under field conditions. For example, the search for a bacterial or protozoan pathogen of the snail hosts which would be useful for biological control has been examined, with little success, only in the laboratory.

One of the more interesting tests of an agent for biological control of an intermediate host of *Schistosoma mansoni* involved the use of the trematode parasite *Ribeiroia marini guadeloupensis* against *Biomphalaria glabrata* (intermediate host of human schistosomes in the western hemisphere). Reproduction of *Biomphalaria glabrata* stops completely when it is infected by this parasite. Field trials involved introduction of millions of eggs of *Ribeiroia* into water which contained *Biomphalaria*. The introduction of this parasite allowed control of the *Biomphalaria* population.

Another area of biological control of snail intermediate hosts of schistosome parasites involves use of another species of snail which will compete against the intermediate host for food or space. In this type of biological control, an exotic snail species is intentionally introduced into the habitat of the snail intermediate host with the aim of eliminating the intermediate host and thereby preventing transmission of the disease.

In such an effort at biological control, it is important that the species to be introduced not be an intermediate host for schistosome parasites or for other medically or economically important parasites. It is also necessary to carry out controlled laboratory experiments with both the snail which is to act as the biological control agent and the snail which is to be eliminated before field trials are performed or before the controlling snail is introduced into a habitat. Further, it is important that the introduced species not be destructive to the habitat in ways not intended. For example, the introduced species should not be destructive to agricultural crops, nor should it be destructive to other, beneficial organisms which are present in the habitat into which it is introduced.

Two species of snails which have received much attention as agents for the biological control of schistosome intermediate hosts are *Marisa cornuarietis* and "*Helisoma*" (= *Planorbella*) *duryi*. These two species of snails have been the most extensively studied of those suggested for use in biological control, although other species, such as *Pomacea*, *Potamopyrgus jenkinsi*, *Bulinus tropicus*, *Tarebia granifera*, *Physella* and *Lymnaea emarginata* have also been suggested as being worthy of consideration. However, *Marisa* and *Planorbella* ("*Helisoma*"), at the present, appear to be the most promising species for biological control of schistosome intermediate hosts.

*Marisa cornuarietis* is a large prosobranch snail which is native to Central and South America. It does not occur naturally in Africa or the Near East. *Marisa cornuarietis* has been studied both in the laboratory and in the field as a competitor against several species of intermediate hosts of schistosomes. It is probable that *Marisa* is an accidental predator and eats the eggs and young of other snails as it browses on aquatic vegetation, but it may also be a willful predator against *Biomphalaria*, *Bulinus* and *Lymnaea*, and probably most other freshwater pulmonate snails, whether or not they are economically important. It also acts as a competitor for food because it can consume large quantities of aquatic vegetation. It may remove so much vegetation from an area that other snail species cannot survive due to lack of food. In this way it can also act as a biological control agent.

In Africa, *Marisa cornuarietis* has been tested against schistosome intermediate hosts in Egypt and Tanzania. *Bulinus truncatus* populations were controlled by *Marisa* under semi-field conditions in Egypt, although this experiment was conducted in a very restricted habitat. *Bulinus nasutus* and *Lymnaea natalensis* were eliminated by *Marisa* in the laboratory in Tanzania. *Marisa* was introduced into the reservoir at the man-made Kisangara Dam in Tanzania, and two years later the naturally occurring populations of *Biomphalaria pfeifferi*, *Lymnaea natalensis* and *Bulinus tropicus* had disappeared. The prosobranch snail *Melanoides tuberculata* continued to live in the reservoir.

*Marisa* has been successfully used as a biological control agent in several field studies. *Marisa* may not always control the intermediate host snails, however, and the amount of vegetative cover may be a major factor in the failure of *Marisa* to do so. For example, in Puerto Rico, *Marisa* was able to temporarily control *Biomphalaria* populations in ponds with 10% vegetation cover, but in ponds with 100% cover there was no decrease in the *Biomphalaria* populations. Evidently, there is no single biological control agent which will be effective in all situations.

The freshwater pulmonate snail *Planorbella* ("Helisoma") *duryi* is another snail species which has been suggested for use as a biological control agent against some snail intermediate hosts of human schistosomes. *Planorbella duryi* is native to North America, and is not found naturally in Africa or the Near East. It has been introduced into at least 16 localities in Africa and the Near East, either intentionally or unintentionally. It can cause problems with identification of species since its shell, under certain ecological conditions, may closely resemble the shell of *Biomphalaria*.

Laboratory research on the interaction between *Planorbella* and *Biomphalaria* and *Bulinus* has shown that *Planorbella* is an efficient competitor and might be effective as a biological control agent, since it can eliminate the intermediate host snails when in the same aquarium with them. The means by which *Planorbella duryi* appears to control intermediate hosts of human schistosomes consists primarily of an inhibition of the development of embryos and the growth of juvenile snails. At one time it had been suggested that *Planorbella duryi* may secrete substances which prevented development and growth of *Biomphalaria* juveniles. Recent research has indicated, however, that the action of *Planorbella* against *Biomphalaria* is based upon other direct interference, such as predation on egg masses and juveniles of *Biomphalaria* by *Planorbella* and upon (possibly) food competition.

The effectiveness of *Planorbella duryi* as a biological control agent under field conditions has not been extensively studied, and it remains to be determined whether *Planorbella* can eliminate natural populations of intermediate host snails when competing in the host snail's natural habitat. However, since *Planorbella duryi*, unfortunately, has been introduced into Africa, possibly some observations on those introduced populations will aid in the evaluation of the role of *Planorbella* in the biological control of schistosome intermediate hosts in those areas.

### Health Education

Schistosomiasis transmission does not occur in Jordan,\* and will not if the program to keep the country free of the snail intermediate hosts is successful. Therefore, the need for a high intensity health education effort is not as great as in those countries that have severe schistosomiasis problems. Nevertheless, health education should not be neglected. The general public, especially in areas where host snails are more likely to become established, should be aware of the disease, what causes it, the parasite's life cycle, the human ecological conditions under which the parasite thrives, and where people can go for diagnosis and treatment should they suspect they have the disease.

Should intermediate host snails for human schistosomes eventually become established in Jordan, then more intensive efforts must be made toward health education concerning the disease and the conditions for its transmission.

\*See footnote, page 4.

### The National Schistosomiasis Control Program in Jordan

Schistosomiasis presents quite a different problem in Jordan than in most other countries engaged in attempts to control the disease. The factor which makes the Jordanian situation unique is that at the present time transmission of the disease has not been discovered.\* This is unexpected in spite of the annual presence of 75,000 to 120,000 migrant workers, of whom a significant number (23.5% of those examined) have schistosomiasis haematobium (urinary schistosomiasis), and the discovery in Jordan on several occasions of the intermediate host snails which transmit the disease. The infected human population comprises only adults who, once in Jordan, are not subjected to the rigors of reinfection. Therefore, no prevalence or intensity rates can be studied. The same situation exists concerning the snails and wild mammals. In view of the uniqueness of the situation, the Government of Jordan had to organize its own program of control having very little collectively to draw upon from the experience of other countries conducting control programs.

One of the outstanding features of the Jordanian control program is the total commitment of the government to provide the resources for the Ministry of Health in its attempt to prevent the establishment of endemic foci where schistosomiasis transmission could occur. The percentage of funds which the Government of Jordan is committing to the control program as compared with other donors is 74% of the entire program. The United States Agency for International Development has contributed 22% and the World Health Organization has contributed 4% of the program cost to date.

The management of the control program is carried out by the Malaria and Schistosomiasis Control Unit, Ministry of Health, assisted when needed by the Parasitology Section, Department of Biological Sciences, University of Jordan. Prevention of parasite transmission has been successful so far, in spite of the presence of both infected migrant workers and the snail hosts. The control program includes the registration and location of all waterbodies in Jordan, treatment of snail-infested areas, and keeping abreast of all new water resource developments.

\*See footnote, page 4.



### Part III. APPENDICES



### Part III. APPENDICES

#### 9. Schistosomiasis

##### A. Urine Filtration Technique for Quantitative or Qualitative Diagnosis of *Schistosoma haematobium* Infection

Urine is best collected between 11 a.m. and 2 p.m. to coincide with the peak urinary *Schistosoma haematobium* egg excretion. The urine may be collected in any type of wide-mouthed container.

Samples are mixed by drawing urine in and out of disposable plastic syringes with a 5 cm extension of straight plastic tubing of the same diameter as the needle adaptor. Ten ml of urine are withdrawn in the syringe. The extension tube is removed and the urine injected through a 13 mm (or 25 mm) diameter Swinnex filter support containing a Nytrel T1 20 HD or Nuclepore filter. After the urine has been completely expressed from the syringe, the syringe is removed, filled with air and reinjected into the filter holder. This procedure is repeated twice to remove excess urine and to force the eggs to adhere to the surface of the filter.

The filter support is then opened and the filter removed with forceps and placed on a glass slide (filter face upwards for the Nytrel filter, filter face down for the Nuclepore filter). In order to observe the eggs on the filter, one drop of saline is pipetted onto the filter to prevent drying. Both filters require moistening with saline to permit adequate visualization of the eggs.

Microscopic examinations are performed under 40x magnification and the number of eggs on the entire filter are counted and recorded. For semi-quantitative examinations, up to 50 eggs may be counted; over 50 eggs per 10 ml urine may be considered as heavy infections.

The same procedure may be followed with the Nuclepore filters, and the filters are not re-used. After addition of one drop of glycerine or mounting media, the Nuclepore filters may be kept in microscope boxes for later evaluation.

## Materials

### Urine Collection

Any type of plastic snap-top or easily sealed container is acceptable. Plastic cups of 120 cc capacity with snap-on lids are available from Mono Container, Ltd., London, England [Item No. H120 U].

### Transport Boxes

If the urine specimens are to be transported, small, shallow, wooden boxes which can be stacked are appropriate. These can be constructed locally after the size of the containers has been determined.

### Urine Examination

#### Plastic Disposable Syringes

For purposes of urine filtration, these are re-usable. A Luer-lok tip, centrally located (not eccentric) is recommended. The syringe is available from Becton-Dickinson, Division of Becton, Dickinson and Company, Rutherford, New Jersey 07070, U.S.A.

#### Plastic Tube Extension

To avoid immersing the syringe in the urine specimen, a 5 cm plastic tube extension fitted to the Luer-lok tip is suggested. The internal diameter of the tube should be 1/8 inch (0.3 cm). Intravenous tubing may also be used. Tubing is available from Arthur H. Thomas Company, Post Office Box 779, Philadelphia, Pennsylvania 19105, U.S.A. [Item No. 9560-H35: tubing 1/8" x 1/16", 100-foot roll].

#### Swinnex Filter Supports

These are available in 13 mm or 25 mm diameters. The larger diameter holder is recommended only for examination of urine samples with excessive sediment by Nucleopore filtration. If Nytrex filters are used, the 13 mm filter support is adequate for all examinations. These filter holders are available from Millipore Corporation, Bedford, Massachusetts

01730, U.S.A., or Millipore SA, Zone Industrielle, 67020 Molsheim, France [Items: SX 00 01300, Swinnex 13 mm; SX 00 02500, Swinnex 25 mm].

## Filters

### Nytrel Filter

This is made from a woven, polyamide, monofilament material, which is available in various mesh sizes. The 20 micron pore-size has been used successfully for filtration of *Schistosoma haematobium* eggs. The appropriate filter size may be cut by hand or punched from material purchased by the square meter. The material is available from L'Union Gazes a Bluter, B.P. 2, 42360 Panissieres, France [Item: Nytrel T1 HD 20 in rolls per m<sup>2</sup>, or precut 12 mm diameter in packages of 500 filters].

**Comment:** This filter is low-cost, re-usable (after washing with common detergents or plain running water each time) for over 5,000 times under field conditions. Examination must be performed shortly after preparation of the sample (the sample cannot be preserved). These filters are best for rapid field surveys in which high sensitivity and quantitation are required. No staining of the sample is necessary. For examination, a compound microscope with mirror/sunlight source is optimal.

### Nuclepore Filter

This is a polycarbonate membrane material which is available in various pore sizes (8 to 14 microns), pre-cut as 13 or 25 mm diameter filters, or as 8 x 10 inch sheets from which filters may be punched. This filter material is available from Nuclepore Corporation, 7035 Commerce Circle, Pleasanton, California 94566, U.S.A., or Comptronix AG, Drugbergstrasse 19, 8810 Horgen 1, Switzerland [Items: 12 micron pore size (No. 110416, 13 mm filter; No. 110616, 25 mm filter; No. 113616, 8 x 10 inch sheets (100); 14 micron pore size (No. 110417, 13 mm filter; No. 110617, 25 mm filter; No. 113616, 8 x 10 inch sheets (100))].

**Comment:** These filters are relatively expensive if purchased as pre-cut filters. Cost may be reduced by punching filters from 8 x 10 inch sheets. Cost is the only drawback for use of this filter in large-scale surveys. Only the 12 and 14 micron size are recommended for field work, since the smaller pore sizes may clog with blood or other sediment. Specimens may be preserved by adding one drop of glycerine at

the time of preparation, or when they are fixed to the slide with tissue mounting media. These filters are ideal for accurate quantitative examination in research. The membrane is delicate and may be re-used several times, if care is taken in washing it. The filter may be cleaned with detergent.

#### Filter Punch

Either 13 or 25 mm filter punches are available to punch either Nytrel or Nuclepore filters from C.S. Osborne and Company, Harrison, New Jersey 07029, U.S.A. [Article No. 149 Arch Punch], or Bugnard Cie, Chemin de Montelly 46, CH-1000 Lausanne 20, Switzerland [Item No. 24.620 (specify size of punch needed)].

#### Forceps

Flat forceps are recommended to handle the filters. The forceps are available from Arthur H. Thomas Company, Post Office Box 779, Philadelphia, Pennsylvania 19105, U.S.A. [Items No. 5-17-G15 Forceps Membrane and No. 5117-F20 Forceps].

#### Microscope Slides

Microscope slides (2 x 3 inches or 5 x 8 cm) may be used to examine six to eight 13 mm filters at a time.

#### Marking Pencils

These are useful for identifying slides and for marking containers. Wax pencils are the cheapest.

#### Hand Tally Counters

Accurate egg counts are facilitated by using hand tally counters, which can be obtained from almost any equipment supply agent. For convenience, two suppliers are listed here: Arthur H. Thomas Company, Post Office Box 779, Philadelphia, Pennsylvania 19105, U.S.A. [Items: No. 3297-H50, Counter; No. 3297-H60, Counter, Hand Tally]; Fisher Scientific Company, 711 Forbes Avenue, Pittsburgh, Pennsylvania 15219, U.S.A. [Item: No. 7-905, Counter].

Pasteur Pipettes

Rubber Bulbs to fit Pasteur Pipettes

250 ml Beaker

## B. Skin Test (Intradermal Reaction)

### General Aspects

The immune apparatus of man responds to the infection by schistosomes pathogenic to man (for example, *Schistosoma mansoni* and *Schistosoma haematobium*) with the formation of antibodies. These immune reactions are increasingly applied as methods for the diagnosis of schistosomiasis. In many cases in which the microscopic diagnosis (demonstration of ova in feces or biopsy specimens) fails, a clinically-based suspicion may be supported by a positive serum reaction and confirmed by the simultaneous employment of several serological methods. Besides the usual serological methods like indirect hemagglutination, indirect fluorescence and the complement fixation test, the intradermal reaction has gained particular importance as an *in vivo* method. [According to Kagan et al. (1961), a schistosome antigen for the skin test for any of the schistosome species is preferably to be prepared from adult *Schistosoma mansoni* worms, not only because of the specificity and sensitivity of the reactions but also because of greater yield of antigen.] Furthermore, it has been found that an unequivocally linear correlation exists between skin sensitivity and nitrogen concentration of the injected antigen in infected persons as measured by the mean reaction area of the appearing wheal. Therefore, a standardization of the skin test antigen by means of the quantitative determination of the nitrogen content (0.03 mg/N/ml) has been suggested by the World Health Organization.

The schistosomiasis skin test can be used because of its relatively high sensitivity (93-100%) and specificity, its simplicity of performance together with low costs, and the quickly available results. It can be used to confirm the clinical diagnoses, for epidemiological investigations, and for preliminary screening before mass treatment of people with chemotherapeutic agents.

### Principle of Reaction

Patients suffering from schistosomiasis show already at an early stage of the disease a specific skin sensitivity four to eight weeks after invasion of the infectious agent, the cercaria. This sensitivity is stable for the total duration of the infection, even for some years after successful chemotherapeutic treatment of the patient. After the injection of a *Schistosoma*-antigen into the skin of a schistosomiasis-infected person, a histamine-type skin reaction (immediate type reaction), which occurs on account of existing specific antibodies, takes place within 10 to 20 minutes in the form of a wheal (induration) with erythema formation.

### Reagents

#### Composition and Properties

##### 1) *Schistosoma* skin test antigen

This is an extract from adult schistosomes (*Schistosoma mansoni*), which is mixed with a small amount of a physiologic buffer. The antigen is biologically and chemically standardized (0.03 mg/N/ml) and can be obtained from Behringwerke AG, Germany, in a sterile, pyrogen-free, lyophilized form, with a preservative (1:10,000 sodium benzene-parathyl-mercuri-mercapto-benzene-sulfonate) added.

##### 2) *Schistosoma* skin test control solution

The control solution is a sterile, pyrogen-free, stabilized, buffered sodium chloride solution.

##### 3) Solvent for *Schistosoma* skin test antigen

Sterile, pyrogen-free distilled water.

### Instruments for the Test

Tuberculin syringes, sterile (0.25 ml or 1.0 ml); needles for injection; sterile 27-gauge (0.4 mm) disposable plastic; measuring stencil (see Fig. 54); filter paper; ballpoint pen; stopwatch; alcohol; and swab.



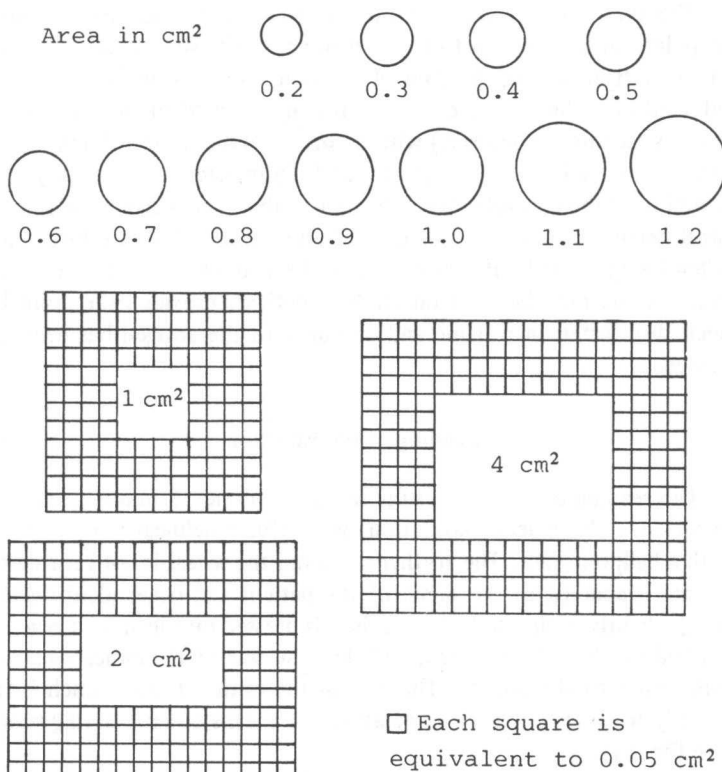


FIG. 54. Measuring stencil for use in the Skin Test Procedure (adapted from Pelligrino, 1957).

Interpretation:  $0.1 \text{ cm}^2$  to  $0.4 \text{ cm}^2$  = negative;  $0.5 \text{ cm}^2$  to  $0.9 \text{ cm}^2$  = doubtful, especially in children up to 12 years of age [if the skin test was performed on the forearm, it is recommended to repeat the test in the area of the nape];  $1.0 \text{ cm}^2$  and larger, mostly irregularly formed (pseudopods) = positive.

### Test Procedure

#### 1) Dissolving of antigen

The dry substance is reconstituted by adding 2 ml of the solvent (pyrogen-free, sterile, distilled water).

2) According to the World Health Organization, the intradermal test is to be carried out as follows.

The skin test is performed on the inside of the forearm (or interscapular in children up to 12 years of age). The site of administration of the antigen and of the control solution is cleaned with alcohol, disinfected and allowed to dry. For the injection of the antigen, sterile needles (see prescribed size) with a corresponding tuberculin syringe are used. Exactly 0.05 ml antigen is carefully injected intradermally. The injection of the control solution is done in the same way contralaterally. Steel needles should be washed and sterilized at 120°C (not by boiling) when being re-used. If a platinum needle is used for the injection, the same needle may be used on another patient, provided the point has been disinfected in a flame and one drop of the antigen has been discarded.

#### Reading of the Reaction

The reading of the test results should be done 15 minutes after the injection. The wheal (induration) is carefully delineated on the skin with a ballpoint pen. The erythema around the wheal is not considered. A filter paper (with the name of the patient and other identification data), slightly moistened with alcohol, is pressed on the area of reaction marked by the ballpoint pen, and thus the size of the indicated area is transferred to the paper. The size of the outlined area, which is frequently irregularly formed, is measured by means of a measuring stencil (see Fig. 54).

According to recommendations of the World Health Organization, the reactivity of adults and children, as well as sex and perhaps the race, should be taken into consideration when interpreting the test. It is generally agreed that the intensity of skin reactions in adults is expected to be stronger than in children. Furthermore, the reaction is stronger in males than in females and varies in intensity among non-white and white persons. For the evaluation of chemotherapeutic investigations, the skin test is not suitable, since the skin sensitivity remains undiminished for several years after successful therapy. Non-specific reactions may occur if people contact avian cercariae (causing swimmer's itch) or bovine schistosomes and, to a small degree, with other trematode diseases (such as fascioliasis, chlonorchiasis, paragonomiasis).

#### Preventing Errors

The injection of the *Schistosoma*-antigen and the control solution

must always be carried out strictly intradermally. In case, by error, a subcutaneous injection is made, the test must be repeated at another site of the skin of the forearm or nape.

Exactly 0.05 ml of the antigen has to be given.

The antigen drop must be visible at the point of the needle before the injection is performed. Only when the antigen drop is visible is the correct dosage possible.

Dissolved *Schistosoma* antigen should be stored in a refrigerator and attention should be paid that the bottles are properly closed to prevent drying up and the solution is free from turbidity which indicates contamination. Properly stored, dissolved antigen keeps up to four weeks. It should be good for that period of time as long as no discoloration or flocculation occurs in the solution.

### C. Cellophane Thick Smear Fecal Examination Technique

The cellophane thick smear fecal examination technique was introduced by Kato & Miura (1954). Subsequent to the first English publication of this technique by Komiya & Kobayashi (1966), many modifications of the original technique had appeared. This technique has proved to be a useful and efficient means of diagnosis of intestinal helminthic infections, as well as *Schistosoma* species.

#### Materials

1) Glass microscope slides; the ordinary slides 25 x 75 mm are appropriate.

2) Flat-sided wooden applicator sticks or similar devices made of plastic or other material.

3) Cellophane, wettable, 40 to 50  $\mu$  in thickness in 22 (or 25) mm x 30 to 35 mm strips.

4) Glycerine-malachite green solution (50% aqueous solution: 100 ml distilled water; 100 ml glycerine; 1 ml 3% aqueous malachite green (or 3% aqueous methylene blue)).

5) Screen: either a wire steel cloth (105 mesh stainless steel bolting cloth) or plastic screen (60 mesh per square inch or 250  $\mu$  mesh size).

(A stainless steel screen welded onto an oval steel ring with a handle is re-usable.)

6) Templates: these plates can be made from stainless steel (Peters et al., 1980), plastic Kato-Katz or cardboard (Japanese Association for Parasitic Control). The size can range from 20 mm to 50 mm and may be dependent on local requirements. In any event, the templates will permit accurate delivery of a standard stool specimen and quantitative egg counts can be determined.

#### Procedure

1) Soak the cellophane strips in the 50% glycerine-malachite green (or methylene blue) solution for at least 24 hours before use.

2) Transfer a small amount of feces (for example, 25 mg) onto a piece of scrap paper (newspaper is ideal).

3) Press the screen on top of the fecal sample.

4) Using the flat-sided wooden (or plastic) applicator, scrape across the upper surface of the screen to sieve the fecal sample.

5) Place a template on a clean microscope slide.

6) Transfer a small amount of sieved fecal material into the hole of the template and carefully fill the hole; level (flat) the fecal material with the applicator stick.

7) Remove the template carefully so that all the fecal material is left on the slide and none is left sticking to the template.

8) Cover the fecal sample on the slide with a glycerine-soaked cellophane strip.

9) If an excess of glycerine is present on the upper surface of the cellophane, wipe off the excess with a small piece of toilet paper or absorbent tissue.

10) Invert the microscope slide and press the fecal sample against the cellophane on a smooth surface (a piece of tile or flat polished stone is ideal) to spread the sample evenly.

### 11) Lift up the slide.

The preparation of the slide is now complete. It may be necessary to wipe off excess glycerine with a piece of toilet paper.

### Proper Reading of the Slides

Slides with 25 mg of fecal material can be read in one to three hours. Slides with larger amounts of material should be kept at room temperature for about 24 hours **before** microscopic examination. By placing the latter slides in an incubator (40°C) or under an intense fluorescent or incandescent light, the slides may be read a few hours earlier.

To facilitate the reading, one or two drops of eosin in 0.9% saline at a dilution of 1:100 may be placed on the upper surface of the cellophane, left for three to five minutes, then wiped off with a piece of toilet paper or other absorbent paper. This method permits improved visualization of *Schistosoma* eggs, as well as hookworm eggs, which are usually not visible otherwise.

Many different recommendations have been made regarding reading of the slides. Ideally, each laboratory should review the reading procedure carefully to determine the optimal time for microscopic examination of the slides.

### Shipment and Storage of the Slides

Cellophane thick smear slides can be prepared in the field, stored in microscopic slide boxes and shipped great distances, which permits examination at a central laboratory if required.

Under most conditions, if the proper grade of cellophane and adequate concentration of glycerine are used, slides can be kept up to six months without deteriorating. If the cellophane curls or dries, it can be remoistened with a drop of water, glycerine or eosin in saline. Reconstitution is not perfect, but at least practical. Again, each laboratory can adjust these recommendations for storage according to individual requirements.

### Thick or Hard Stool Specimens

The major complaint about the thick smear technique from most

microscopists has been that it is impossible to visualize the helminth ova in some hard (constipated) stool specimens. In such cases, the following suggestions may be helpful.

1) After preparation by the standard method, be sure to wait 24 to 48 hours before counting eggs on these slides. The slide may clear slowly.

2) Remake another pair of samples on a large (3 x 3 inches) microscope slide and use a slightly larger piece of cellophane (35 x 35 mm) and press very hard to flatten the specimen as much as possible.

3) When the large slide is used, the stool specimen may be softened by adding saline or glycerine to it on the microscope slide before applying the cellophane.

#### Suppliers of Complete Kits

- 1) Japanese Association for Parasitic Control  
c/o Hokenkaikan  
1-1 Ichigaya-Sadohara  
Shinjuku-ku, Tokyo, Japan
- 2) OVO-FEC kits (Kato-Katz) for 100 or 500 examinations:  
Boehringer Mannheim Bioquimica S.A.  
Rua Nair, 170 - Olaria  
Rio de Janeiro, Brazil

#### Supplier of Individual Items

##### Wettable Cellophane

Description: No. 124 PD, thickness 33  $\mu$ , weighs approximately 50 g/m<sup>2</sup>

Bulk supplier: E.I. Dupont Nemours  
Plastic Products and Resins Department  
Wilmington, Delaware 19898, U.S.A.

Description: Rhone Poul enc 500 P 601

Bulk supplier: Rhone Poul enc S.A., Paris, France

Product supplier (in rolls of 50 meters x 22 mm):

Celloclair  
CH 4410 Liestal, Switzerland

### Screen

#### Stainless Steel Screen

Description: 105 mesh, stainless steel, bolting cloth

Supplier: W.S. Tyler, Inc.  
8200 Tyler Boulevard  
Mentor, Ohio 44040, U.S.A.

#### Nylon Screen

Description: TT250, HD 16243 A

Supplier: L'Union Gazes a Bluter, SA  
Place de la Liberte, BP 2  
42360 Panissieres, France

#### Plastic Screen

Description: 60 mesh/square inch (CS-5)

Supplier: Japanese Association of Parasite Control  
c/o Hokenkaikan, 1-1 Ichigaya-Sadohara  
Shinjuku-ku, Tokyo, Japan

### D. AMS III Egg Concentration Method\*

#### Qualitative

- 1) Break up into very minute pieces 0.5 gm of feces with 5 ml acid-

\*Developed by Hunter, Hodges, Jaynes, Diamond & Ingalls (1948).

sulfate solution mixture\*\*.

2) Strain through two mono-layers of loose-textured surgical gauze (moistened with the acid-sulfate mixture) into a 15 ml centrifugation tube [too many layers of gauze, or fine-textured gauze, will filter out nearly all the eggs].

3) Wash three times by centrifugation at 1700 - 2100 rpm for 1.5 to 3 minutes, decanting the supernatant fluid each time and mixing the sediment with fresh acid-sulfate mixture.

4) After decanting, add 5 ml acid-sulfate mixture, 3 drops Triton NE, and 5 ml refrigerated ether and shake for 30 seconds and centrifuge for 1 minute.

5) Break the surface ring at its interface and decant the fluid in the centrifugation tube; swab the tube down to the sediment with a cotton swab.

6) Add normal saline to the 0.4 ml mark on the centrifugation tube, mix the sediment with the saline solution, then pipette the mixture on to 1 or 2 slides and cover with a coverglass.

7) Examine the material on the slide under low power (100-150x) of a compound microscope.

#### Semiquantitative

1) Break up into very minute pieces 1 gm of feces and mix with 9 ml acid-sulfate mixture (that is, a 1:10 dilution).

2) Take 1 ml of the fecal suspension and strain it through two layers of gauze (moistened with the acid-sulfate mixture) into a 15 ml centrifugation tube.

\*\* Acid-sulfate solution mixture:

- a) prepare acid solution by adding 40 ml of concentrated hydrochloric acid to 60 ml of water (or 400 ml HCl + 600 ml H<sub>2</sub>O);
- b) prepare a sodium sulfate solution by dissolving 9.6 gm anhydrous sodium sulfate in 100 ml of water s.g. (specific gravity of 1.08);
- c) combine equal amounts of (a) and (b).



- 3)
  - 4)
  - 5)
  - 6)
  - 7)
- } Same steps as the qualitative procedure above

8) E.P.G.F. (eggs per gram of feces) = no. total eggs in sediment  $\times$  10.

#### E. Viability of Schistosome Eggs

Following recovery of schistosome eggs from either urine or feces, examination of the eggs should be performed in order to determine their viability. The presence of living miracidia within the eggs indicates an active infection that may require therapy. Determination of the viability of the miracidium within the egg may be conducted by either one of two simple procedures: by determining whether the miracidia in the egg cases will hatch, or by direct microscopic examination to observe whether the egg cases contain living embryos. Miracidia of either species (*Schistosoma haematobium* or *Schistosoma mansoni*) may begin to hatch within a very short time, or up to several hours, when placed in 10 volumes of dechlorinated water, or in spring water. Or, the recovered eggs can then be examined under a microscope to determine viability.

The eggs of *Schistosoma haematobium* (see Fig. 55,a) recovered from the urine (24-hour urine specimen without preservatives) of infected persons can easily be obtained after sedimentation of the specimen.

To recover the eggs of *Schistosoma mansoni* (see Fig. 55,b) from feces of infected persons, the procedure that can be used is as follows.

- 1) Thoroughly mix a fecal specimen in a 1.8% aqueous saline solution and strain the mixture through two layers of gauze;
- 2) Allow the material to settle and pour off the supernatant fluid. Repeat this step twice;
- 3) Decant the saline solution, add dechlorinated water or spring water.

To determine viability of schistosome eggs by the hatching method,

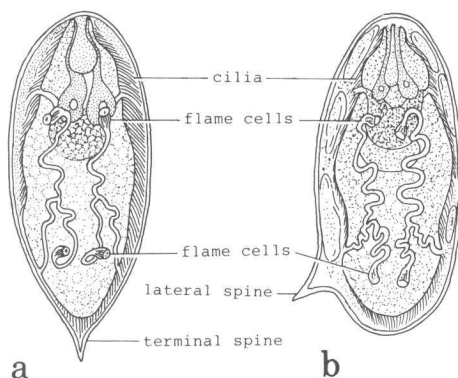


FIG. 55. Fully embryonated miracidia in their egg cases. a, *Schistosoma haematobium*; b, *Schistosoma mansoni*. (From Faust, 1949.)

pour the solution containing the eggs into a 500 or 1,000 ml side arm flask (see Fig. 56). Cover the flask with black paper or aluminum foil, leaving 1-2 ml of fluid in the side arm of the flask exposed to light. Place a bright light at the side of the side arm of the flask opposite the surface of the exposed water. Since the miracidia are phototropic (attracted to light), they will swim into the side arm of the flask where they can be seen in the illuminated water, either by the naked eye or with the use of a hand lens.

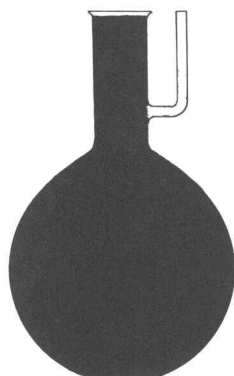


FIG. 56. Side arm flask for hatching schistosome miracidia. (See McMullen & Beaver, 1945.)

## 10. Malacology

### F. Snail Identification

#### General

All freshwater snails possess a shell, which is a hard, calcareous structure that covers the soft parts of the animal, providing protection (Fig. 57). In most snails, the shell is twisted in a continually increasing spiral.

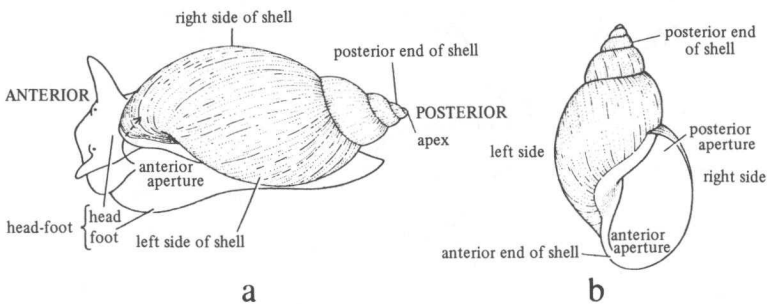


FIG. 57. a, An active crawling snail, showing the position and orientation of its protective shell; b, the same shell, in apertural view, in which the animal is not shown.

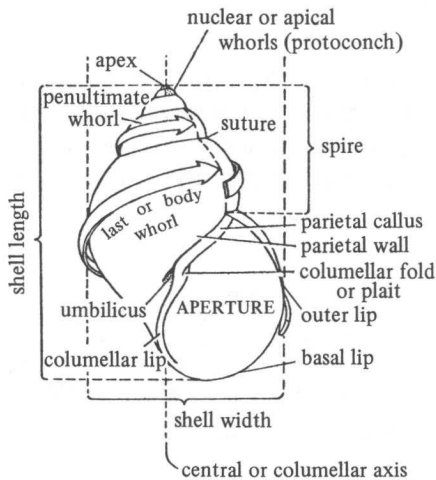


FIG. 58. Shell terminology.

The characteristics of this shell are different for each species, but within each species the appearance of the shell is constant, except for slight individual variations, differences due to age of the snail, and sometimes minor diversity as exhibited between different local populations. Because of the constant appearance of the shell for each species, its characteristics are very important in species recognition, and usually for generic and familial placement as well. For that reason, it is important to know the terminology for the various parts of a snail's shell (Fig. 58). Especially useful are the size (Fig. 59) and general form of the shell.

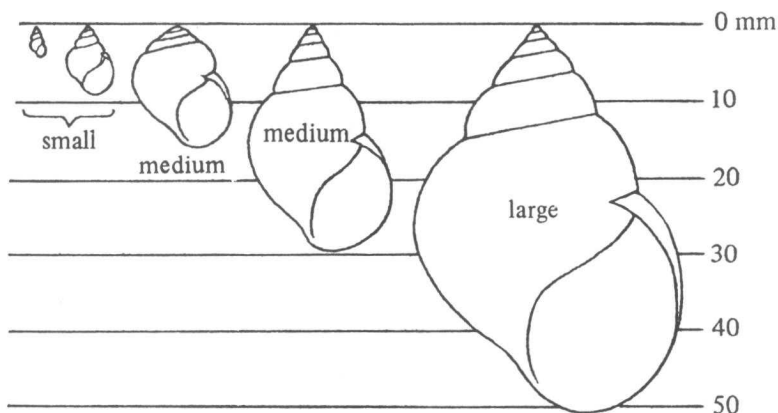


FIG. 59. Shell sizes: less than 2 mm = *minute*; 2-10 mm = *small*; 11-30 mm = *medium*; over 30 mm = *large*.

Among the many species, the shell may take various shapes. The shells of the different species may vary from very elongate to globose, depressed and discoidal (Fig. 60). Elongate shells may be oval, cylindrical or conical, and those with conical shapes vary from narrowly conic to widely

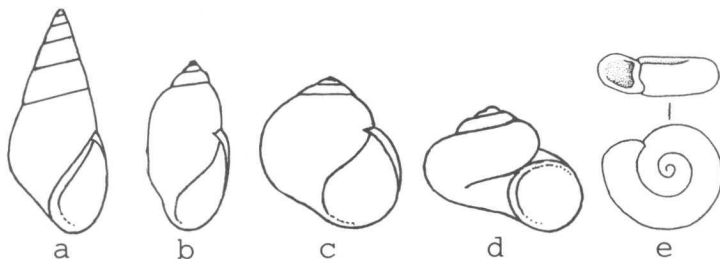


FIG. 60. Shell shapes. a, Elongate conic; b, elongate cylindric; c, globose; d, depressed; e, discoidal.

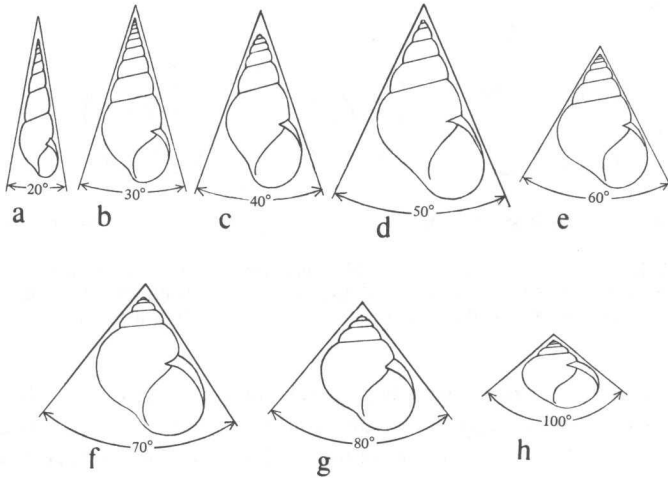


FIG. 61. Terminology of conical shells. The degrees of the various spire angles are given below each shell. a, Narrowly conic; b, elongately conic; c, narrowly subovately conic; d, subovately conic; e, ovately conic; f, subglobose conic; g, globose conic; h, widely (depressed) conic.

conic (Fig. 61). The shell may be longer than wide, or wider than long (the columella determining the antero-posterior (length/width) axis). Its coils (whorls) may turn either to the right (clockwise) or to the left (counter-clockwise) (Fig. 62), be round, angular, shouldered or flattened (Fig. 63), and have shallow or impressed sutures (Fig. 64). The shell

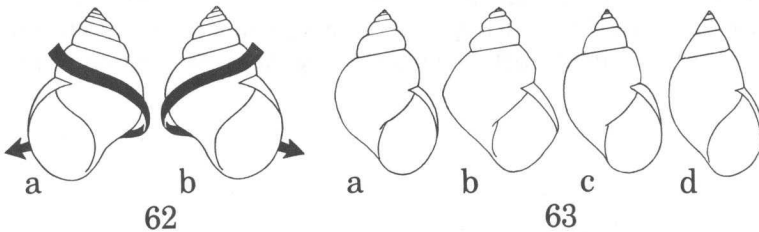


FIG. 62. Direction of coiling of snail shells. a, A shell coiled to the left, that is, *sinistral*; b, shell coiled to the right, that is, *dextral*.

FIG. 63. Shell terminology. a, Shell with well-rounded whorls; b, shell with angular whorls; c, shell with shouldered whorls; d, shell with flattened whorls.

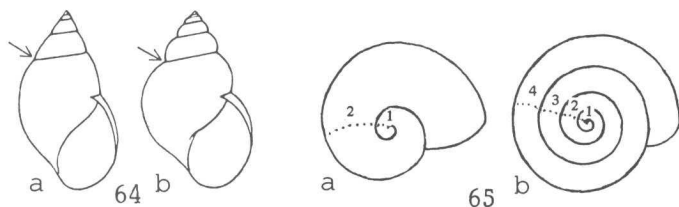


FIG. 64. Shell suture terminology. a, Shallow sutures; b, indented or impressed sutures.

FIG. 65. a, Shell with few, rapidly increasing whorls; b, shell with many, slowly increasing whorls. The dotted lines on the whorls illustrate the method of counting whorls; the shell in a has  $2\frac{1}{2}$  whorls, the shell in b has  $4\frac{1}{2}$  whorls.

may have few or many whorls (Fig. 65), may lack an opening (umbilicus) at its base, or may have either a narrow or wide umbilical opening (Fig. 66). The columella or central axial column of the shell may be

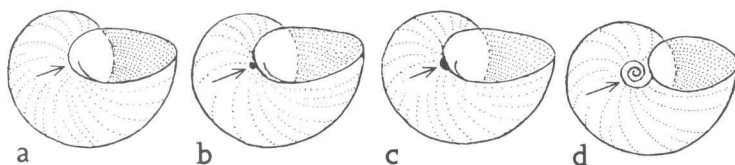


FIG. 66. a, An imperforate shell; b, a perforate shell; c, a rimately perforate shell; d, an umbilicate shell.

either twisted or straight and may or may not end abruptly (Fig. 67). The outer lip of the shell may be either straight or variously curved and is sometimes turned back or reflected (Fig. 68). The surface of the

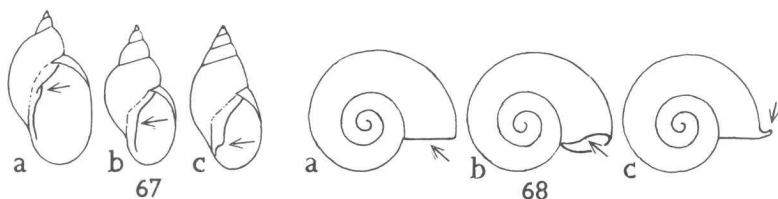


FIG. 67. a, Shell with a twisted columella; b, shell with a straight columella; c, shell with a truncate columella.

FIG. 68. a, Shell with a straight apertural lip; b, shell with a curved apertural lip; c, shell with a reflected apertural lip.

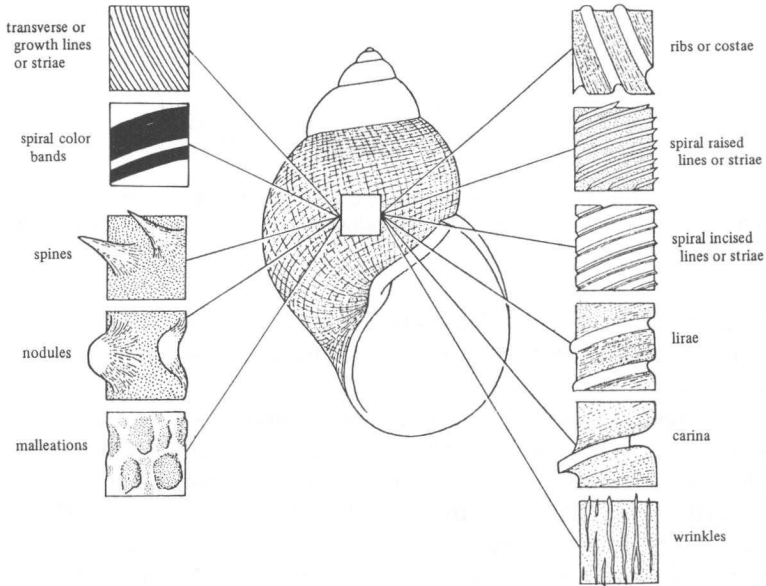


FIG. 69. Shell surface markings.

shell may be marked in various ways (that is, differentially colored or sculptured (Fig. 69)), or simply may be unicolorous and smooth. The outline of the shell aperture ("mouth") may take many forms due to the shape and relation of the whorls to each other. The aperture may or may not be closed by a cover (operculum) (Figs. 70, 71), which itself

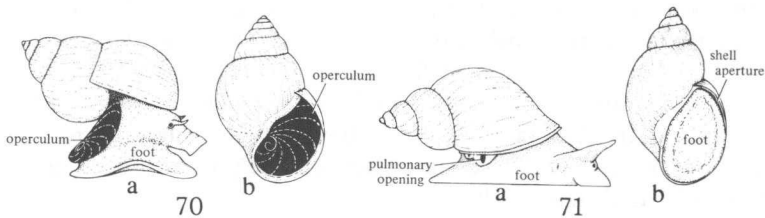


FIG. 70. An operculated snail, that is, one that carries an operculum attached to its dorsal posterior foot. a, Position of the operculum when the snail is active; b, position of the operculum when the snail has withdrawn into its shell.

FIG. 71. A non-operculated (that is, a pulmonate) snail. It does not have a protective operculum to seal the shell aperture when the snail has withdrawn into its shell. a, An active snail; b, an inactive snail, withdrawn into its shell, with only the surface of its foot showing.

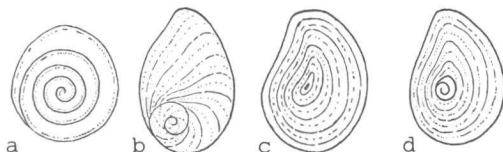


FIG. 72. Types of opercula. a, Multispiral; b, paucispiral; c, concentric; d, concentric with spiral nucleus. The operculum shown in a is round; b, c and d are oval opercula.

has important recognition characters. The operculum may be round, oval or spindle-shaped, and concentric, paucispiral or multispiral, depending on the way in which it is formed (Fig. 72).

In some snail groups, aspects of the soft anatomy are essential for identification, because the various taxa in these groups have shells which are relatively uniform or have few distinctive characteristics. This, of course, makes identification difficult for specimens of which only empty shells are available. However, identification can be aided by careful inspection of the shell illustrations and by taking into account the known distributions of the various species.

#### Snail Intermediate Hosts of Human Schistosomes in the Near East

All snail intermediate hosts for human schistosomes in the Mediterranean region, the Near East, Iran and Africa are members of the group of invertebrates called gastropods (that is, they belong to the molluscan class Gastropoda), which includes all mollusks that are snails. Gastropods, or snails, are animals which usually have a coiled shell carried on top of a long, narrow part of the body, referred to as the head-foot. This type of shell distinguishes snails from the molluscan class Bivalvia (the clams), in which the animals have two shells, or "valves", surrounding their bodies. Both snails and clams are likely to be found during surveys for freshwater snails.

Snails may live in marine, freshwater or terrestrial environments, but all snail intermediate hosts of human schistosomes live in fresh water. Within the freshwater habitat, snails belonging to two different subgroups or subclasses, the Prosobranchia and the Pulmonata, may be found. Both of these subclasses have many species, and, since some



species of both subgroups are common and widespread in the Near East, they will be encountered frequently in snail surveys. The prosobranch snails can be distinguished most easily from pulmonate snails by the examination of living specimens, or specimens which were alive when preserved. Prosobranch snails have a rounded or oblong hardened structure, the operculum (see Fig. 70, p. 127), attached to the top of the foot at the posterior end of the animal. When disturbed, or when resting, prosobranch snails retract into their shells and, when doing so, the operculum is the last structure to enter the shell aperture (the opening of the shell). The operculum functions to seal the aperture when the snail is retracted. When the operculum is seen on the head-foot of an undisturbed prosobranch snail (Fig. 70,a), or seen sealing the opening of the shell of a retracted snail (Fig. 70,b), the observer can be certain that the snail in question is not an intermediate host for human schistosomes in either the Near East or Africa.

The only snail intermediate hosts of human schistosomes in the Near East and Africa belong to the gastropod subclass Pulmonata. Pulmonate snails breathe air by means of a lung. In addition to those living in fresh water, there are also many pulmonate species living on land, but no land snail is an intermediate host for human schistosomes. All intermediate hosts for human schistosomes in the Near East and Africa are aquatic, and all of them inhabit only fresh water.

Within the freshwater pulmonate snail subgroup living in the Near East and Africa, there are four major subdivisions, the "families". These four families are Lymnaeidae, Physidae, Planorbidae and Ancyliidae. Of these four families, *only members of the Planorbidae are intermediate hosts for human schistosomiasis* in the Near East. Therefore, it is desirable to be able to distinguish between members of the different freshwater pulmonate snail families in order to determine if a potential intermediate host snail has been discovered. This may be done by observing certain structures (characters) which enable the observer to determine or identify the family of pulmonates to which a particular specimen belongs.

To determine whether a particular specimen is a potential intermediate host for human schistosomiasis, follow the identification key below. [In the identification key, the reader is presented with a successive series of two opposing choices about a character of the shell or animal to be identified. The choice that pertains to the shell being identified will lead the reader to the next set of two opposing characters. This procedure is followed until a couplet leads the reader to a name rather than

## Identification Key for Intermediate Host Snails of Human Schistosomes in the Near East and Africa

- 4(3) Snail's shell discoidal (see Figs. 49-52, p. 66) .....  
 ..... Family PLANORBIDAE (in part)  
 [some species are **intermediate hosts** for human schistosomes; see below for further identification]

Snail's shell elongated ..... 5

- 5(4) Snail's shell elongated and glossy and smooth; animal with finger-like processes extending from the edge of the mantle; snail lacks a pseudobranch; blood colorless (see Fig. 45, p. 58) ..... Family PHYSIDAE  
 [not intermediate hosts for human schistosomes]

Snail's shell elongated, but not glossy; animal with pseudobranch extending from the left side; blood red. Family PLANORBIDAE (in part) (see Figs. 46-48, p. 61) ..... Genus *Bulinus*  
 [all species in the Near East are **intermediate hosts** for *Schistosoma haematobium*]

Once a snail has been determined to be a member of the family Planorbidae, it is possible that the snail is an intermediate host for human schistosomes. However, not all planorbids are intermediate hosts. The Planorbidae contain a number of different genera of snails. Each genus is composed of snail species which share certain characters, and the genera may be identified by the use of those characters.

Among the discoidal Planorbidae, only two genera are found in Jordan, *Planorbis* and *Gyraulus*, both of which can be distinguished easily from *Biomphalaria arabica*, the only human schistosome intermediate host with a discoidal shell in the Near East. The shells of *Gyraulus* (see Fig. 39, p. 57) are no more than 6 mm in diameter (generally less), while the shells of *Biomphalaria* are at least 10 mm (usually

more in diameter, and may get as large as 15 mm in diameter and 4 mm in height (see Figs. 49-52). Should *Biomphalaria arabica* appear in Jordan, the local species with which it would most likely be confused is *Planorbis planorbis*. But, *Planorbis* is smaller than *Biomphalaria arabica* and its shell is not as high (see Fig. 38, p. 57); *Biomphalaria arabica* is generally larger and has a higher shell at all stages of growth. Also, *Planorbis planorbis* commonly has a keeled shell. In addition, the two genera may be clearly distinguished from each other by inspecting aspects of their internal anatomy. The prostate glands of the male reproductive systems differ from each other. In *Biomphalaria*, the lobes of the prostate gland empty directly into the vas deferens (Fig. 73,a), while in *Planorbis*, the lobes of the prostate empty into a separate prostatic duct (Fig. 73,b), rather than directly into the vas deferens.

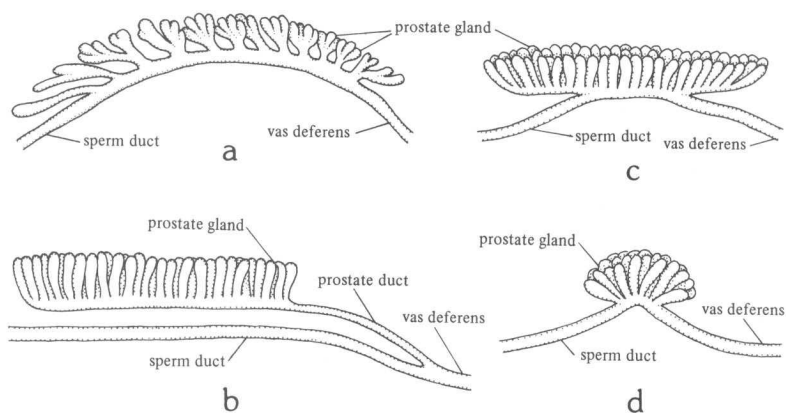


FIG. 73. Portion of the male reproductive systems to show the forms of the prostate glands and how they empty into the vas deferens. a, *Biomphalaria*; b, *Planorbis*; c, *Planorbella*; d, *Indoplanorbis*.

Another species of snail with a discoidal shell, *Indoplanorbis exustus*, is reported from Muscat, Oman, but it is possible that it may be more widely distributed. The shell of *Indoplanorbis* differs from *Biomphalaria* by its higher shell. The shell of *Biomphalaria* is less than 6 mm high, while that of *Indoplanorbis* is greater than 6 mm high. Also, the shell of *Indoplanorbis* is often larger and may reach 25 mm in diameter. A more definite way to identify *Indoplanorbis exustus* is by examination of the copulatory organ. *Indoplanorbis exustus* is closely related to

*Bulinus* and possesses an ultrapenis (Fig. 74,c,d) (see below for a description of the ultrapenis of *Bulinus*). *Biomphalaria* does not have an ultrapenis (Fig. 74,a).

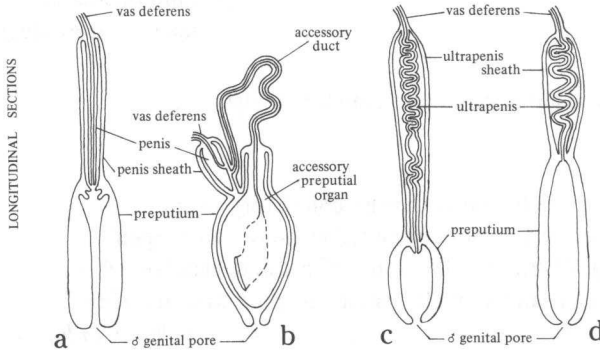


FIG. 74. Copulatory organs of a, *Biomphalaria*; b, *Planorbella*; c, *Indoplanorbis*; d, *Bulinus*.

There is another genus of snails with a discoidal shell which may eventually get to Jordan and if so may cause misidentification. This genus is *Planorbella* (pertinent species were formerly assigned to the genus *Helisoma*). *Planorbella* is a North American genus which has been introduced into Africa (including nearby Egypt) and Saudi Arabia, either by accident or deliberately as an experimental snail for biological control of schistosome intermediate hosts. The distribution of *Planorbella* is enlarging and may soon include other countries of the Near East. The shell of *Planorbella* resembles the shell of *Indoplanorbis*, both of which are higher than the shell of most species of *Biomphalaria*. However, the shape of the shell of *Planorbella* may vary depending on the environment, and may, at times, be extremely difficult to distinguish from *Biomphalaria*. Positive identification of *Planorbella* can be made by observation of the copulatory apparatus (Fig. 74,b), which differs from that of both *Biomphalaria* and *Indoplanorbis*. The copulatory organ of *Planorbella* contains an accessory preputial organ which connects to the penis sheath by an externally visible duct. Neither *Biomphalaria* nor *Indoplanorbis* has such a structure.

The purpose of the following identification key is to determine whether or not a discoidal-shelled snail is a potential intermediate host for *Schistosoma mansoni*.

## Identification Key for Snails with Discoidal Shells

- 1 Shell of adult snail less than 2 mm high (see Fig. 39,  
p. 57) . . . . . *Gyraulus*  
[not intermediate hosts for  
human schistosomes]

Shell of adult snail more than 2 mm high . . . . . 2

- 2(1) Shell more than 6 mm high; copulatory organ with  
either an accessory preputial gland or an ultrapenis  
(Fig. 74, b, c, p. 133); lobes of prostate gland bunched  
into a rounded or elongated, compact structure (Fig.  
73, c, d) . . . . . *Planorbella* or *Indoplanorbis*  
[not intermediate hosts for  
human schistosomes]

Shell less than 6 mm high . . . . . 3

- 3(2) Shell up to 3 mm high and may have a distinct circular  
ridge (carina) on the edge of the shell (Fig. 38, p. 57);  
lobes of the prostate gland enter the vas deferens via a  
separate duct (Fig. 73, b, p. 132) . . . . . *Planorbis*  
[not intermediate hosts for  
human schistosomes]

Shell more than 3 mm high; lobes of prostate are  
attached directly to the vas deferens in a long row  
(Fig. 73, a) . . . . . *Biomphalaria*  
[*Biomphalaria arabica* is  
the **intermediate** host of  
*Schistosoma mansoni* in  
the Arabian Peninsula]

The main intermediate snail host for *Schistosoma haematobium* in  
the Near Eastern countries is *Bulinus truncatus*. This snail species has

been reported from Jordan, Israel, Syria, Iraq, Iran, Lebanon, Saudi Arabia and North and South Yemen. However, species of *Bulinus* other than *Bulinus truncatus* have been reported also to be the intermediate hosts of *Schistosoma haematobium* in Saudi Arabia and North and South Yemen, even though *Bulinus truncatus* is present in those countries. Thus, in South Yemen, Oman and Saudi Arabia, *Bulinus wrighti* is a potential or actual intermediate host of *Schistosoma haematobium*, and *Bulinus beccarii* is an additional intermediate host for *Schistosoma haematobium* in Saudi Arabia and North and South Yemen.

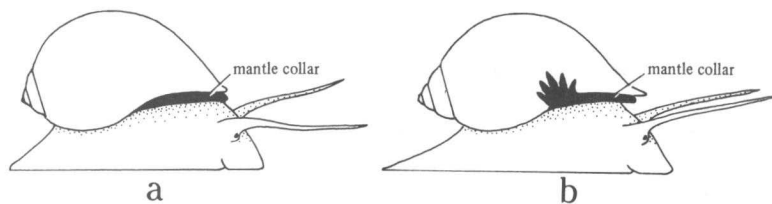
The genus *Bulinus* is composed of snail species which possess a sinistral shell (a left-handed shell) which clearly distinguishes *Bulinus* from nearly all other non-discoidal species of freshwater snails. The shell of *Bulinus* may be globose or elongated, and differs from *Biomphalaria* (the intermediate host of *Schistosoma mansoni*) in that the shell of *Bulinus* is not flat and discoidal, but rather has an elevated spire. The only snail genus in the Near East and Africa with which *Bulinus* can likely be confused is *Physella*. *Physella* also has a sinistral, elongate shell. It is very important that the distinction between the two genera be learned, since *Physella acuta* is very widely distributed and is also very likely to be found living in the same habitat with *Bulinus*. Misidentification could lead to mismanagement of available resources for snail control (since *Physella* is not an intermediate host for human schistosomes) or to a failure to recognize that control measures are necessary.

*Bulinus* and *Physella* can be distinguished from each other in that the shell of *Physella* is generally shinier, smoother and more pointed at the apex than is the shell of *Bulinus*. The spire of the *Physella* shell is generally not as strongly indented at the suture lines as the shell of *Bulinus*. But, examination of living or preserved animals is a more certain means of distinguishing between the two genera. The major differences between *Bulinus* and *Physella* which assist identification are:

- 1) *Bulinus* possesses red blood while *Physella* does not. Squashing a living snail will cause the release of red fluid if the snail is *Bulinus*; the fluid will be colorless if the snail is *Physella*;

- 2) *Bulinus* possesses an accessory respiratory structure (the pseudobranch) on its left side under the mantle collar, while *Physella* does not (Fig. 75). The pseudobranch has the appearance somewhat of a feather and can be seen projecting from underneath the edge of the shell on a snail which is sitting or moving, if left undisturbed by the observer;

- 3) *Physella* possesses finger-like projections on the edge of the mantle

FIG. 75. a, *Bulinus*; b, *Physella*.

(mantle digitations) (Fig. 75). These digitations can be observed most easily on the right margin of the mantle, from which they project over the surface of the shell. The digitations are generally held tightly against the shell. *Bulinus* has no mantle digitation;

4) The penial apparatus of the two genera are quite different and distinctive. *Bulinus* possesses an ultrapenis (Fig. 74,d), which is not found in *Physella*. The ultrapenis consists of a long and somewhat coiled, eversible tube which is inside the penial sheath. This inner tube is connected at both ends to the penial sheath so that the ultrapenis has no end which lies free in the cavity of the penial sheath. The ultrapenis also has many small projections from its inner surface which can be observed through the walls of the penial sheath, or, if the ultrapenis is severed lengthwise, can be observed projecting from the inner wall of the ultrapenis. The penial complex of *Physella acuta* is very different from that of *Bulinus*. The penis of *Physella* is a long, pointed structure which is attached only at the inner end of the penial sheath. The pointed end of the penis is not connected to the penial sheath and thus lies free within the cavity of the penial sheath. There are no projections from the walls of the penis of *Physella* as there are from the inner walls of the ultrapenis of *Bulinus*. In addition, the preputium of *Physella acuta* possesses an internal gland which is visible externally as a swollen knob on the penial sheath. *Bulinus* possesses no such gland on its penial sheath. Further, in *Bulinus truncatus*, sometimes many, or most, of the individuals of a population will lack either a portion or the entire penial apparatus. Such a defective penial complex rarely occurs in *Physella*;

5) The posterior end of the foot of *Bulinus truncatus* is rounded, while that of *Physella* is distinctly pointed (Fig. 75);

6) Finally, the egg masses of the two genera are also quite different. The *Physella* egg mass has a rounded surface, and is elongated, transparent, jelly-like and soft in consistency. The individual eggs are nearly



colorless and are distributed throughout the egg mass. The egg mass of *Bulinus* is flat, of a harder consistency than that of *Physella*, and is circular or oval in outline. The eggs of *Bulinus* are in one layer, frequently very close to one another or touching each other. When the eggs are in contact, they lose their rounded appearance and are flat on the side(s) where two eggs touch. The eggs of *Bulinus* are yellow. Thus, the egg masses of *Bulinus* and *Physella* can be used to differentiate between the two genera. If, however, egg masses are discovered in surveys without finding snails, it is generally not possible to determine with certainty that *Bulinus* is present, since the egg mass of *Bulinus* is very similar to egg masses of other Planorbidae and hence definite identification cannot be made. Of course, if the eggs are allowed to hatch and the young grown to an appropriate size, identification can then be made.

The following identification key is to identify snails with sinistral shells and elevated (not discoidal) spires.

#### Identification Key for Snails with Sinistral, High-Spired Shells

- 1 Snail's shell shiny and smooth; animal with finger-like projections extending from the edge of the mantle (see Fig. 75,b); copulatory organ with a large, externally visible swelling on the preputium; snail lacks a pseudo-branch; blood colorless (not red) . . . . . *Physella*  
[not intermediate hosts for  
human schistosomes]
  
- Snail's shell elongated, not especially smooth or shiny;  
suture lines well indented; animal with an accessory  
respiratory structure (pseudobranch) extending from  
beneath the left margin of the aperture of the shell (see  
Fig. 75,a); copulatory organ without an externally  
visible swelling on the preputium, but, rather, with an  
ultrapenis; blood red. Genus *Bulinus* . . . . . 2

- 2(1) Snail's shell distinctly narrow, higher than wide (Fig. 76,a) . . . . . *Bulinus beccarii*  
 [Intermediate host for  
*Schistosoma haematobi-*  
*um*, restricted to the  
 Arabian Peninsula]

Snail's shell not distinctly narrow, but rounded instead . . . . . 3

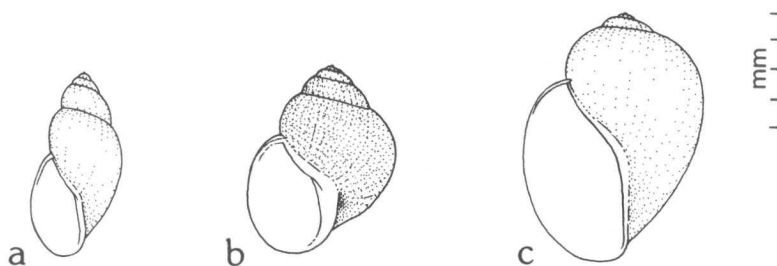


FIG. 76. Shells of a, *Bulinus beccarii*; b, *Bulinus wrighti*; and c, *Bulinus truncatus*.

- 3(2) Snail's shell small (usually 5-7 mm or less in length), reticulate (that is, ribs on shell are crossed by spiral grooves), globose, nearly as wide as high, with wide umbilicus (Fig. 76,b) . . . . . *Bulinus wrighti*  
 [Intermediate host for  
*Schistosoma haematobi-*  
*um*, restricted to the  
 Arabian Peninsula]

Snail's shell larger, thick, not distinctly round, without reticulation, umbilicus narrow (Fig. 76,c) . . *Bulinus truncatus*  
 [Intermediate host for  
*Schistosoma haematobi-*  
*um*, widely distributed in  
 the Middle East]

## G. Snail Surveys

The necessary equipment to conduct snail field work consists of the following: scoop nets, specimen containers, labels, boots, gloves, 70% alcohol, thermometer and forceps. The scoop consists of a wire mesh (for example, about 18 x 32 cm) attached to one end of a wood or metal pole one or more meters in length. Uniform sweeps through the water and vegetation, bringing up bottom debris, are made with the scoop. In examining each scoop for snails, great care must be taken both in handling the fragile snails and avoiding water contact. Wading boots and rubber gloves must be used while collecting snails: the snails are transferred from scoop to specimen container by means of a pair of forceps for later examination. Ethyl or isopropyl alcohol (70%) should always be readily available if one gets wet accidentally. The alcohol can be applied to the skin to kill any cercariae that may have been in the water.

Snail surveys may be either qualitative or quantitative. A qualitative survey determines only or mainly the species of snails present at the various localities. A quantitative survey determines the relative abundance of snails present, and, when done in conjunction with an ecological survey, relates snails' occurrence and abundance to habitat characteristics and ecological conditions.

The preliminary step in doing a malacological/ecological study is to map the area being surveyed, noting for each habitat the water level, aquatic and terrestrial vegetation, water quality, pH of water, air, water and microhabitat temperature, as well as avian, mammalian and invertebrate life forms. Then areas are designated for snail sweeps with the scoop nets. The method is to carry out X number of sweeps over Y meters of water per Z units of time. It is preferred that the same person using the same scoop and technique carry out this sampling procedure to ensure the reliability of acquired data. If more than one scoop net is used, they should have the same size and type of net. Besides recording the number of snails present, one notes the presence or absence of snail egg masses, the number of eggs per egg mass and the size of snails. All these data are important in measuring the effectiveness of molluscicide treatment by doing comparative snail density studies before and after treatment. (See Snail Survey and Water Analysis Forms, below).

In the laboratory, it must be determined whether or not the collected snails are infected with trematode parasites. It is recommended that

two techniques be employed for this purpose. The first technique involves crushing of the gastropod shell to expose the internal organs. The organs are gently teased apart to search for parasite larval stages by use of a stereoscopic microscope. The cercariae which may be found in such an inspection may be of various types, belonging to a variety of parasite species infecting a number of different kinds of host animals. The human schistosome cercariae may be distinguished from most other cercariae by the absence of eye spots and pharynx, and by their forked tails. The cercariae of nonhuman schistosomes have black eye-spots.

The disadvantage with this snail-crushing technique is that immature larvae (that is, sporocysts without mature cercariae) cannot be identified as to their type or species. Therefore, one has to obtain mature cercariae in order to study their morphology. The second technique involves exposing collected snails to light for a few hours in order to induce shedding of cercariae. If cercariae have been emitted, these are transferred by pipette to a glass slide and a cover slip is added. A weak dilution (1 part stain to 1000 parts water, by volume) of methylene blue is added and cercariae are killed by gentle heating of the slide for a few seconds with a flame from a lit match. Cercaria identification can then be attempted. Snails that do not emit cercariae initially may do so at a later time after the cercariae have matured within the snail. Therefore, it may be useful to maintain a sampling of snails for re-examination after one or more weeks.

Species identification of collected snails involves careful observation and the use of identification characters exhibited by the snails (see pp. 123-138). For the identification of many species, the use of a hand lens is required, and for some species a stereoscopic microscope is necessary. Special attention should be given to the characteristics of the schistosome-bearing snail species.

## Snail Survey Form

Date \_\_\_\_\_ Time \_\_\_\_\_ District \_\_\_\_\_

Map, gazetteer or local  
name of water body \_\_\_\_\_

Locality \_\_\_\_\_

## Water Body

Natural: river, creek, lake \_\_\_\_\_

Man made: reservoir, irrigation canal, fish pond \_\_\_\_\_

Permanent, temporary, seasonal, stagnant,  
clear, muddy \_\_\_\_\_

Substratum \_\_\_\_\_

(Boulders, rocks, concrete, gravel, sand, clay, silt, humus,  
decaying matter, mixture of more than one of the preceding)

Turbidity: high, medium, low

Current: fast, medium, slow

Dimensions of water body: Length: \_\_\_\_\_ Estimated area: \_\_\_\_\_

Width: \_\_\_\_\_ Estimated volume: \_\_\_\_\_

Depth: \_\_\_\_\_

Margins \_\_\_\_\_

Nature: regular, irregular, straight, curved \_\_\_\_\_

Slope: steep, medium, shallow \_\_\_\_\_

Adjacent land: forested, brush, meadow, desert, cultivated,  
human inhabited \_\_\_\_\_

## Drainage Source

Springs, seepage, irrigation \_\_\_\_\_

Fresh water \_\_\_\_\_ Brackish water \_\_\_\_\_

## Pollution

Industrial, human excrement \_\_\_\_\_

Animal excrement, garbage and domestic waste \_\_\_\_\_

## Aquatic vegetation

Kinds \_\_\_\_\_

Amount \_\_\_\_\_

Character (floating, emergent, submerged) \_\_\_\_\_

## Aquatic Animals

Birds \_\_\_\_\_

Mammals \_\_\_\_\_

Others \_\_\_\_\_

Sun exposure of habitat \_\_\_\_\_

Season \_\_\_\_\_ Air temperature \_\_\_\_\_ Water temp. \_\_\_\_\_

Relative humidity \_\_\_\_\_ Wind \_\_\_\_\_

Method of collection \_\_\_\_\_

Density of snails (abundant, medium, rare, none) \_\_\_\_\_

## Size % in sample:

small \_\_\_\_\_

medium \_\_\_\_\_

large \_\_\_\_\_

Egg masses (present, absent) \_\_\_\_\_

Species present: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Trematode infection: \_\_\_\_\_

Nematode infection: \_\_\_\_\_

Other parasites: \_\_\_\_\_

Remarks: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

## Water Analysis Form

Date \_\_\_\_\_ Time \_\_\_\_\_ District \_\_\_\_\_

Locality \_\_\_\_\_

Site No. \_\_\_\_\_

Test					
Temperature °C					
pH					
Alkalinity ppm					
Acidity ppm					
Carbon dioxide ppm					
Chloride ppm					
Chromium ppm					
Copper ppm					
Hardness ppm					
Iron ppm					
Manganese ppm					
Nitrogen					
Ammonia ppm					
Nitrate ppm					
Nitrite ppm					
Oxygen dissolved ppm					
Phosphorus reactive					
Phosphorus A/O					
hydrolyzable ppm					
Silica ppm					
Sulfate ppm					
Sulfide ppm					
Sulfite ppm					
Turbidity FTU					

Snails Collected: \_\_\_\_\_

\_\_\_\_\_

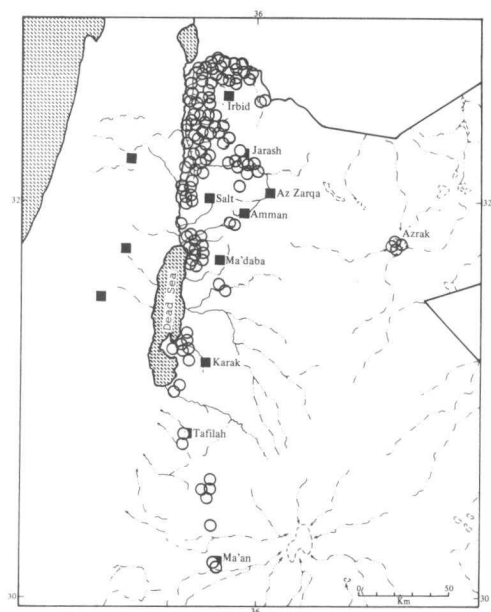
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## H. Distribution of Freshwater Snails in Jordan

The fresh waters of Jordan were surveyed for aquatic snails during 1980-82. That was an intensive investigation, in which over 200 sites were carefully searched. The sites include rivers (R), streams (St), primary (C1) and secondary (C2) canals (C), springs (S), mineral-water springs (Sm), spring pools (Sp), artesian wells (AW), swamps (Sw), ponds (P) and dams (D). Each place where snails were collected was assigned a Site Number. The sites are listed below (List 1) by consecutive site numbers, with type of water body, species of aquatic snails found, locality name, and date visited given for each site. The geographic localities of these sites are shown in Map 1.

Seventeen species of aquatic snails were found during the survey. (One species, *Melanopsis praemorsa*, was represented in the collections by two subspecies.) These snail species and subspecies are presented in List 2 (pp. 164-166), listed in the same taxonomic order that they occur in the section on Freshwater Snail Fauna of Jordan (pp. 27-58). The sites where each species was found are listed by numbers under the various species and subspecies. The site numbers in List 2 correspond to the site numbers in List 1 (pp. 145-164). The distributions of the species are shown in Maps 2-13 (pp. 158-163).



MAP 1. Distribution of sites (open circles) in Jordan from which freshwater snails were collected during the 1980-82 survey.



## List 1. Survey Sites and Their Snails

Site No.	Site Type	Snail Species	Locality	Date
1	Sw*	<i>Semisalsa contempta</i> <i>Pseudamnicola gaillardotii</i> <i>Pseudamnicola solitaria</i>	Beer Al-Azraq	5/4/81
2	S	<i>Theodoxus macrii</i> <i>Melanoides tuberculata</i> <i>Melanopsis praemorsa buccinoidea</i>	Swaimeh Spring	5/4/81
3	S	<i>Melanoides tuberculata</i> <i>Melanopsis praemorsa buccinoidea</i>	Hamdi Al-Anees Spring	5/4/81
4	St	<i>Theodoxus macrii</i> <i>Melanoides tuberculata</i> <i>Melanopsis praemorsa buccinoidea</i>	Othaymat	4/4/81
5	St	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i>	Quasmiya	30/3/81
6	S	<i>Melanopsis praemorsa buccinoidea</i>	Mahateet Spring	30/3/81
7	St	<i>Melanopsis praemorsa buccinoidea</i>	Dokhanya Wadi	30/3/81
8	S	<i>Melanopsis praemorsa buccinoidea</i>	Nakhla Spring	30/3/81
9	Sm	<i>Pseudamnicola gaillardotii</i> <i>Melanoides tuberculata</i>	Zarat Spring	30/3/81
10	S	<i>Pseudamnicola gaillardotii</i> <i>Theodoxus macrii</i> <i>Melanoides tuberculata</i> <i>Melanopsis praemorsa buccinoidea</i>	Barakat Spring	30/3/81
11	S	<i>Melanoides tuberculata</i> <i>Melanopsis praemorsa buccinoidea</i>	Mahafeet Spring	30/3/81
12	St	<i>Melanoides tuberculata</i> <i>Melanopsis praemorsa buccinoidea</i>	Draybeh	31/3/81
13	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i>	Halwah Spring	31/3/81

\*AW = artesian well; C = canal; C1 = primary canal; C2 = secondary canal; D = dam; P = man-made pond; R = river; S = spring; Sm = mineral-water spring; Sp = spring pool; St = stream; Sw = swamp.

14	D	<i>Melanoides tuberculata</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Physella acuta</i> <i>Lymnaea truncatula</i>	Kafreen Dam	5/4/81
15	S	<i>Theodoxus jordani</i> <i>Melanopsis praemorsa costata</i> <i>Physella acuta</i>	Twahin Al-Sukar	3/3/81
16	P	<i>Melanopsis praemorsa costata</i> <i>Physella acuta</i>	Arda Triangle	4/3/81
17	P	<i>Physella acuta</i>	Kabed Lake	8/3/81
18	Sw	<i>Melanoides tuberculata</i>	Om Ghorba	4/4/81
19	C2	<i>Melanopsis praemorsa costata</i> <i>Physella acuta</i>	Ghour Kabed Canal	9/3/81
20	D	<i>Physella acuta</i>	South Shounah Dam	31/3/81
21	AW	<i>Melanoides tuberculata</i> <i>Physella acuta</i>	Al-Karama Wells	29/3/81
22	C1	<i>Melanopsis praemorsa buccinoidea</i> <i>Theodoxus jordani</i> <i>Melanoides tuberculata</i> <i>Physella acuta</i>	Moasher farm	20/8/80
23	C1	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i>	Quanyah	3/9/80
24	C2	<i>Melanoides tuberculata</i> <i>Melanopsis praemorsa costata</i> <i>Physella acuta</i>	Swalha	18/8/80
25	C1	<i>Physella acuta</i>	Al-Fazah	3/8/80
26	S	<i>Melanoides tuberculata</i>	Karamah	30/9/80
27	C1	<i>Melanopsis praemorsa costata</i>	Abu Zeguh Bridge	25/8/80
28	S	<i>Theodoxus jordani</i> <i>Melanoides tuberculata</i> <i>Physella acuta</i>	Dair Ala	24/8/80
29	Sw	<i>Melanoides tuberculata</i> <i>Melanopsis praemorsa costata</i> <i>Physella acuta</i>	Masri Triangle	17/8/80
30	C1	<i>Physella acuta</i>	Swalha	18/8/80
31	D	<i>Melanopsis praemorsa costata</i> <i>Physella acuta</i>	Tal Al-Dahab	6/8/80

32	C1	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa costata</i> <i>Physella acuta</i>	Al-Diat	24/8/80
33	S	<i>Physella acuta</i>	Fanosh Spring	1/3/81
34	C1	<i>Melanopsis praemorsa costata</i> <i>Physella acuta</i>	Dair Alla	27/8/80
35	S	<i>Melanopsis praemorsa costata</i>	Abdell Haleem Spring	3/3/81
36	S	<i>Physella acuta</i>	University Farm Station	3/22/81
37a	Sw	<i>Planorbis planorbis</i>	Al-Azraq	9/9/80
37b	Sw	<i>Semisalsa longiscata</i>	Dashah-Azraq	9/9/80
38	P	<i>Theodoxus macrii</i> <i>Melanoides tuberculata</i> <i>Melanopsis praemorsa costata</i> <i>Pseudamnicola</i> sp.	Azraq Druze	8/9/80
39	S	<i>Semisalsa longiscata</i>	Asad Spring/ Azraq	8/9/80
40	Sw	<i>Lymnaea natalensis</i>	Berjes/Azraq	9/9/80
41	D	<i>Physella acuta</i>	Shoeabe Dam	30/9/80
42	Sw	<i>Pseudamnicola gaillardotii</i>	Bast Al-Faras	29/9/80
43	AW	<i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i>	Jedyaab Wells	3/3/81
44	P	<i>Bulinus truncatus</i> (dead shells) <i>Melanopsis praemorsa buccinoidea</i>	Al-Birkteen	14/9/80
45	R	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa costata</i> <i>Physella acuta</i>	Damyah Bridge	24/8/80
46	St	<i>Melanopsis praemorsa buccinoidea</i>	Al-Waleh Wadi	21/8/80
47	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i>	Al-Deak Spring	30/12/80
48	St	<i>Melanopsis praemorsa buccinoidea</i>	Ma'an	13/11/80
49	S	<i>Melanopsis praemorsa buccinoidea</i>	Abu Zyad Spring	16/12/80
50	S	<i>Melanopsis praemorsa buccinoidea</i>	Halaka Spring	9/12/80
51	S	<i>Melanopsis praemorsa costata</i>	Barseem Spring	5/1/81

52	Sp	<i>Physella acuta</i>	Issa Spring	8/12/80
53	S	<i>Melanopsis praemorsa buccinoidea</i>	Aleyah Spring	31/12/80
54	S	<i>Physella acuta</i>	Sokhnah Spring	6/12/80
55	S	<i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i>	Kofer Assad Spring	24/11/80
56	S	<i>Theodoxus macrui</i>	Bayda Spring	10/11/81
57	S	<i>Theodoxus macrui</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i>	Tal Arbaeen Spring	5/1/81
58a	S	<i>Melanopsis praemorsa buccinoidea</i>	Al-Maleh Spring	29/12/80
58b	S	<i>Melanopsis praemorsa buccinoidea</i>	Northern Maleh Spring	29/12/80
59	St	<i>Theodoxus macrui</i> <i>Melanoides praemorsa buccinoidea</i>	Wadi Ziglab	15/12/80
60	S	<i>Melanopsis praemorsa buccinoidea</i>	Kasim Spring	8/12/80
61	S	<i>Physella acuta</i>	Aid Spring	25/1/81
62	S	<i>Physella acuta</i>	Nabaa' Spring	8/12/81
63	S	<i>Melanopsis praemorsa buccinoidea</i>	Abu besseh Spring	8/12/81
64	Sm	<i>Melanopsis praemorsa buccinoidea</i>	Tal Zarah	27/11/80
65	Sp	<i>Theodoxus macrui</i> <i>Melanoides tuberculata</i> <i>Melanopsis praemorsa costata</i> <i>Bithynia philalensis</i> <i>Bulinus truncatus</i>	Shaik Hussain Spring	8/1/81
66	St	<i>Melanopsis praemorsa buccinoidea</i>	Wadi Ziglab	19/11/80
67	St	<i>Theodoxus macrui</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i>	Jorf Wadi	22/1/81
68	C1	<i>Theodoxus jordani</i> <i>Melanopsis praemorsa costata</i> <i>Physella acuta</i>	East Jordan Canal	2/12/80
69	S	<i>Melanopsis praemorsa buccinoidea</i>	Dokan Spring	2/12/80
70	S	<i>Theodoxus macrui</i> <i>Melanopsis praemorsa buccinoidea</i>	Lakna Spring	2/12/80
71	S	<i>Melanopsis praemorsa buccinoidea</i>	Shater Spring	27/11/80

72	St	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i>	Tul Arbueen Outlet	5/1/81
73	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i>	Bayda Spring	5/1/81
74	S	<i>Melanopsis praemorsa costata</i>	Taybah Spring	3/1/81
75	St	<i>Melanopsis praemorsa buccinoidea</i>	Wadi Zahar	21/11/80
76	S	<i>Melanopsis praemorsa buccinoidea</i>	Al-Maleh Southern Spring	31/12/80
77	S	<i>Melanopsis praemorsa buccinoidea</i>	Al-Maleh med. Spring	31/12/80
78	R	<i>Theodoxus macrii</i> <i>Theodoxus jordani</i> <i>Melanoides tuberculata</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i> <i>Physella acuta</i>	Yarmouk River North	17/2/81
79	S	<i>Physella acuta</i>	Said Shameli Spring	9/12/80
80	St	<i>Pseudamnicola gaillardotii</i>	Wadi Al-Mokran	31/3/81
81	S	<i>Semisalsa contempta</i>	Rahib Spring	29/3/81
82	St	<i>Semisalsa contempta</i>	Al-Maleh Wadi	8/3/81
83	St	<i>Melanopsis praemorsa costata</i> <i>Physella acuta</i> <i>Pseudamnicola gaillardotii</i>	Al-Khoor Wadi	4/3/81
84	St	<i>Semisalsa contempta</i>	Okla Wadi	9/3/81
85	St	<i>Lymnaea truncatula</i>	Mohrbeen Spring	7/3/81
86	S	<i>Physella acuta</i>	Al-Kafer Spring	4/3/81
87	St	<i>Melanopsis praemorsa buccinoidea</i>	Nakheel Wadi	10/5/81
88	S	<i>Melanopsis praemorsa costata</i> <i>Physella acuta</i>	Shaheen Spring	7/3/81
89	St	<i>Melanopsis praemorsa buccinoidea</i>	Wadi Al-Ghore	3/3/81
90	S	<i>Semisalsa contempta</i>	Wadi Mokran Spring	10/3/81
91	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i>	Salem yousef Spring	3/1/81

92	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i>	Amayrah Spring	10/3/81
93	S	<i>Melanoides tuberculata</i>	Mafadi Spring	29/3/81
94	Sw	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i> <i>Physella acuta</i>	Bast Al-Halabi	3/3/81
95	S	<i>Physella acuta</i> <i>Bulinus truncatus</i>	Ahmed Spring	14/3/81
96	S	<i>Physella acuta</i>	Abadee Spring	29/3/81
97	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i>	Al-Rasam Spring	29/2/81
98	S	<i>Melanopsis praemorsa buccinoidea</i> <i>Theodoxus macrii</i>	Bata Spring	7/2/81
99	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i> <i>Lymnaea truncatula</i>	Abu Azbi Spring	23/2/81
100	Sp	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i>	Ganam Southern Spring	21/2/81
101	Sp	<i>Physella acuta</i> <i>Lymnaea truncatula</i>	Hamed Spring	9/3/81
102	S	<i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i>	Al-Khesa Spring	23/2/81
103	S	<i>Physella acuta</i>	Abdel Hadi Spring	23/2/81
104	S	<i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i>	Awad Hamod Spring	23/2/81
105	Sw	<i>Physella acuta</i>	Bast Hamdan	7/2/81
106	S	<i>Melanopsis praemorsa buccinoidea</i>	Narjas Spring	3/3/81
107	S	<i>Physella acuta</i> <i>Bulinus truncatus</i>	Tal Sliman Shamalih	22/2/81
108	S	<i>Semisalsa contempta</i> <i>Physella acuta</i>	Al-Karn Spring	8/3/81
109	Sw	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i> <i>Physella acuta</i>	Sharhabeel Basa	25/1/81

## APPENDICES

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110	S	<i>Physella acuta</i>	Bajawi Spring	7/2/81
111	Sw	<i>Physella acuta</i>	Barghasha Spring	7/2/81
112	Sw	<i>Melanoides tuberculata</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Physella acuta</i>	Bast Rayahni	8/2/81
113	S	<i>Melanopsis praemorsa buccinoidea</i>	Abu Hani Spring	22/3/81
114	Sw	<i>Semisalsa contempta</i> <i>Physella acuta</i>	Bast Al-Feleh Mashareh	21/2/81
115	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i>	Slikhat	27/9/80
116	S	<i>Melanoides tuberculata</i> <i>Melanopsis praemorsa costata</i> <i>Physella acuta</i>	Abu Akeel Spring	3/1/81
117	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Lymnaea truncatula</i>	Mageda Spring	1/3/81
118	Sp	<i>Theodoxus macrii</i> <i>Melanoides tuberculata</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i> <i>Physella acuta</i>	Al-Yabis Agricultural Station Spring	3/3/81
119	C2	<i>Theodoxus jordani</i> <i>Melanoides tuberculata</i> <i>Melanopsis praemorsa costata</i> <i>Physella acuta</i>	Abu Sedo	
120	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i>	Shouna Spring	1/3/81
121	St	<i>Melanopsis praemorsa costata</i>	Wadi Abu Kharobah	9/3/81
122	S	<i>Melanopsis praemorsa buccinoidea</i>	Ghanam Spring	8/3/81
123	S	<i>Melanopsis praemorsa buccinoidea</i>	Sa'ada Spring	22/2/81
124	R	<i>Melanopsis praemorsa costata</i>	Yarmouk River	9/12/80
125	S	<i>Melanopsis praemorsa buccinoidea</i>	Tal Salman Spring South	22/2/81
126	St	<i>Melanopsis praemorsa buccinoidea</i>	Masbeerah Spring	8/3/81

127	S + Sw	<i>Melanoides tuberculata</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i> <i>Physella acuta</i> <i>Bulinus truncatus</i>	Zour Al-Hamam	10/3/81
128	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i> <i>Physella acuta</i>	Gholah Spring	3/3/81
129	St	<i>Melanoides tuberculata</i> <i>Physella acuta</i>	Shahadat Wadi	8/3/81
130	S	<i>Melanopsis praemorsa buccinoidea</i>	Marazal Spring	3/3/81
131	S	<i>Melanopsis praemorsa buccinoidea</i>	Amayrah Spring	2/3/81
132	Sw	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i>	Zour Ambeerh	25/3/81
133	S	<i>Melanopsis praemorsa costata</i> <i>Physella acuta</i>	Tahtamoni Spring	3/3/81
134	S	<i>Melanopsis praemorsa buccinoidea</i>	Mnawer Spring	21/2/81
135	St	<i>Semisalsa contempta</i> <i>Pseudamnicola gaillardotii</i> <i>Pseudamnicola solitaria</i>	Al-Kafer Wadi	3/3/81
136	St	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i>	Al-Jarm Wadi	21/2/81
137	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i>	Sofsafa Spring	21/2/81
138	Sp	<i>Physella acuta</i>	Salem Spring	23/2/81
139	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i>	Abu Hajeer Spring	23/2/81
140	S	<i>Melanopsis praemorsa buccinoidea</i>	Yatook Spring	27/4/81
141	S	<i>Melanoides tuberculata</i>	Aspeer Spring	26/4/81
142	S	<i>Melanoides tuberculata</i>	Maslakh Spring	26/4/81
143	S	<i>Melanoides tuberculata</i>	Om Hakeem Spring	27/4/81
144	S	<i>Melanopsis praemorsa buccinoidea</i>	Arabeya Spring	27/4/81



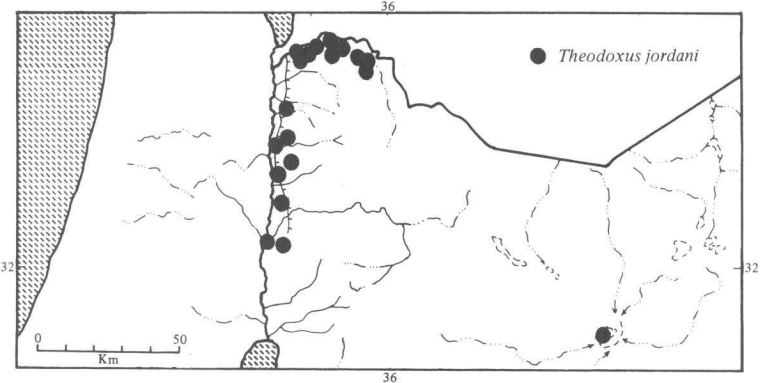
145	St	<i>Theodoxus macrii</i> <i>Melanoides tuberculata</i> <i>Melanopsis praemorsa buccinoidea</i>	Ben Hammadn Spring	
146	St	<i>Theodoxus macrii</i> <i>Melanoides tuberculata</i> <i>Melanopsis praemorsa buccinoidea</i>	Sekeen Spring	26/4/81
147	S	<i>Melanoides tuberculata</i>	Holwa Spring	26/4/81
148	S	<i>Melanoides tuberculata</i>	Abu Koteneh	27/4/81
149	S	<i>Semisalsa contempta</i> <i>Lymnaea truncatula</i>	Debaa Spring	11/5/81
150	S	<i>Lymnaea truncatula</i>	Aymeh Spring	11/5/81
151	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Lymnaea truncatula</i>	La'aban Spring	11/5/81
152	S	<i>Lymnaea truncatula</i>	Lahtha Spring	12/5/81
153	S	<i>Semisalsa contempta</i>	Rehab Spring	11/5/81
154	S	<i>Lymnaea truncatula</i> <i>Gyraulus piscinarum</i>	Ma'an Spring	13/8/81
155	Sw	<i>Theodoxus jordani</i> <i>Melanoides tuberculata</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i> <i>Lymnaea natalensis</i> <i>Bithynia philalensis</i>	Azraq-Southern Azraq	
156	S	<i>Lymnaea truncatula</i> <i>Gyraulus piscinarum</i>	Aeil Spring	16/8/81
157	R	<i>Theodoxus jordani</i> <i>Melanopsis praemorsa buccinoidea</i>	Jordan River King Hussain Bridge	2/12/81
158	R	<i>Theodoxus jordani</i> <i>Melanopsis praemorsa costata</i>	Jordan River Om Al-Short	21/11/81
159	R	<i>Theodoxus jordani</i> <i>Melanopsis praemorsa costata</i> <i>Physella acuta</i> <i>Bithynia philalensis</i>	Jordan River Shaik Hussain Bridge	22/11/81
160	Sw	<i>Physella acuta</i>	Zour Al-Nusayrah Irbid	27/2/82
161	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i>	Om Shrar Irbid	27/2/82

162	St	<i>Lymnaea truncatula</i> <i>Gyraulus piscinarum</i>	Wadi Al-Sigin Hartha-Irbid	29/3/82
163	S	<i>Melanopsis praemorsa buccinoidea</i>	Salleh Spring	
164	St	<i>Lymnaea natalensis</i>	Om Khlal Irbid	27/2/82
165	R	<i>Physella acuta</i> <i>Lymnaea natalensis</i> <i>Pseudamnicola</i> sp.	Zour Al-Breej Yarmouk River	27/2/82
166	S	<i>Theodoxus macrii</i>	Ghazal Spring Irbid	
167	S	<i>Semisalsa contempta</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Lymnaea truncatula</i>	Saham-Irbid	15/3/82
168	S	<i>Melanopsis praemorsa buccinoidea</i>	Ein Harubia Irbid	
169	S	<i>Semisalsa contempta</i>	Aqraba Area	
170	S	<i>Lymnaea truncatula</i>	Na'our	17/3/82
171	Sw	<i>Physella acuta</i> <i>Lymnaea natalensis</i>	Al Braig Irbid	
172	S	<i>Semisalsa contempta</i>	Ein Frouj Irbid	14/3/82
173	S	<i>Theodoxus jordani</i> <i>Melanopsis praemorsa buccinoidea</i>	Ein-Rahoub Irbid	26/3/82
174	S	<i>Melanopsis praemorsa buccinoidea</i> <i>Lymnaea truncatula</i> <i>Semisalsa contempta</i>	E'oun Al-Alka Saham-Irbid	29/3/82
175	S	<i>Theodoxus macrii</i> <i>Gyraulus piscinarum</i>	Eoon Om Ershid Al-Rafeed	29/3/82
176	R	<i>Bithynia philalensis</i> <i>Gyraulus piscinarum</i> <i>Lymnaea truncatula</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Physella acuta</i> <i>Pseudamnicola</i> sp.	Wadi Khaled Irbid	15/3/82
177	Sw	<i>Melanopsis praemorsa buccinoidea</i> <i>Physella acuta</i> <i>Lymnaea truncatula</i>	Mureihat Kabad Al-Ghour/Al-Karama	27/2/82
178	C1	<i>Melanoides tuberculata</i> <i>Melanopsis praemorsa buccinoidea</i>	Qanat Al-Aqlat Saham-Irbid	3/4/82
179	S	<i>Physella acuta</i>	Hemmet Saham	10/5/82

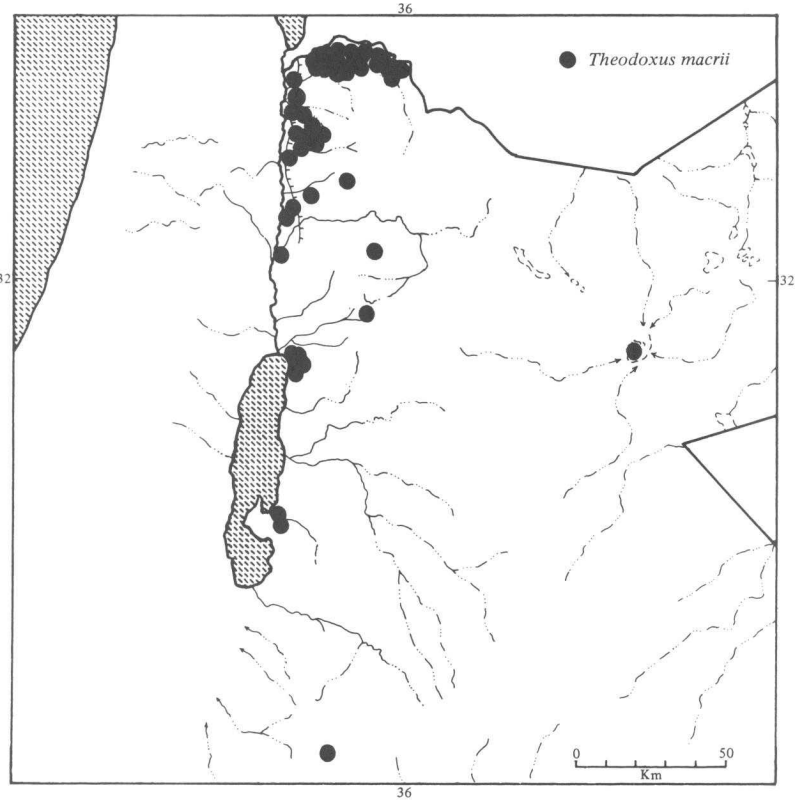
180	S	<i>Melanopsis praemorsa buccinoidea</i> <i>Pseudamnicola gaillardotii</i>	Ein Al-Amayreh Saham-Irbid	3/4/82
181	S	<i>Melanopsis praemorsa buccinoidea</i>	Ein Al-Dellan Al-Mansourah-Irbid	4/4/82
182	S	<i>Melanopsis praemorsa buccinoidea</i>	Ein Deeb Saham-Irbid	3/4/82
183	S	<i>Melanopsis praemorsa buccinoidea</i>	Ein Al-Sahn Al-Mansourah	4/4/82
184	St	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i>	Iraq Al-Amir Wadi Al-Sir	19/5/82
185	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i>	Khillat Al-Ein Saham-Irbid	6/4/82
186	Sw	<i>Physella acuta</i> <i>Lymnaea natalensis</i>	Zour Abu Al- Ghosh NW Aqraba-Irbid	10/5/82
187	S	<i>Theodoxus macrii</i> <i>Gyraulus piscinarum</i>	Ein Om Ershid Al-Rafeed-Irbid	
188	S	<i>Melanopsis praemorsa buccinoidea</i>	Ein Al-Magaren Kufr Soum-Irbid	18/4/82
189	Sw	<i>Pseudamnicola gaillardotii</i>	Basat Al-Faras Kebed-Al-Karama	30/4/82
190	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i>	Ein Eish Al- Rumman Saham-Irbid	3/4/82
191	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i>	Ein Al-Monqat Samar	18/4/82
192	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i>	Ein Al-Fatouha Kufr Soum	18/4/82
193	Sw	<i>Gyraulus piscinarum</i> <i>Physella acuta</i> <i>Pseudamnicola</i> sp.	Zour Al-Nees	10/5/82
194	S	<i>Lymnaea truncatula</i>	Ein Al-Lataifeh Saham-Irbid	21/4/82
195	S	<i>Melanopsis praemorsa buccinoidea</i>	Ein Al-Tayyah Irbid	4/4/82
196	S	<i>Melanopsis praemorsa buccinoidea</i> <i>Semisalsa contempta</i>	Ein Al-Habees Saham-Irbid	19/4/82

197	Sw	<i>Physella acuta</i> <i>Bithynia philalensis</i>	Al-Tarfeh Swamps Yarmouk River	7/4/82
198	S	<i>Melanopsis praemorsa buccinoidea</i>	Ein Issa Saham-Irbid	12/5/82
199	St	<i>Physella acuta</i> <i>Lymnaea natalensis</i>	Wadi Zeizon Irbid	7/4/82
200	S	<i>Physella acuta</i>	Ein Al-Sarayah	28/11/81
201	R	<i>Theodoxus jordani</i> <i>Melanopsis praemorsa costata</i>	Yarmouk River	28/11/81
202	R	<i>Theodoxus jordani</i> <i>Melanopsis praemorsa costata</i>	Yarmouk River	28/11/81
203	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i>	Sheha & Sokar Spring	29/11/81
204	St	<i>Theodoxus jordani</i> <i>Melanopsis praemorsa costata</i>	Al-Magarin	29/11/81
205	St	<i>Theodoxus jordani</i> <i>Melanopsis praemorsa costata</i> <i>Physella acuta</i> <i>Lymnaea truncatula</i>	Zizon Spring	29/11/81
206	R	<i>Theodoxus jordani</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i> <i>Lymnaea truncatula</i>	Mokhibeh Yarmouk River	28/11/81
207	Sm	<i>Melanopsis praemorsa buccinoidea</i>	Hemma Spring	28/11/81
208	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i>	Aqraba Spring Irbid	7/12/81
209	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i>	Doflah Spring	7/12/81
210	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i>	Sa'ud Spring	7/12/81
211	S	<i>Melanopsis praemorsa buccinoidea</i> <i>Theodoxus macrii</i>	Sab'ee Spring	9/11/81
212	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i>	Hajala Spring	9/12/81
213	S	<i>Melanopsis praemorsa buccinoidea</i>	Yobla Spring Irbid	9/12/81
214	S	<i>Lymnaea truncatula</i>	Om Qreen Spring	13/12/81

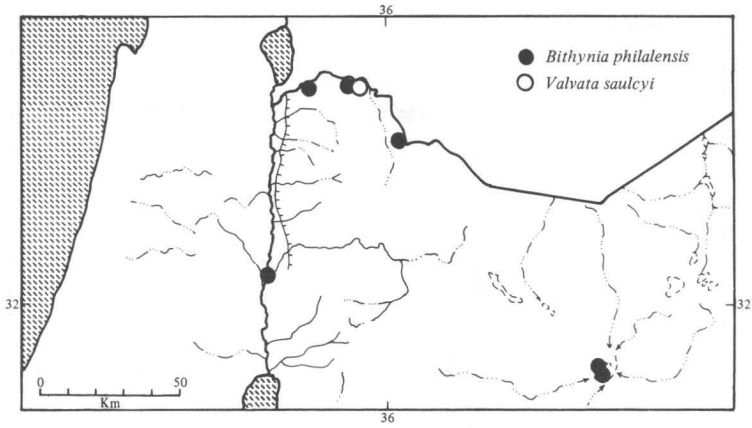
215	S	<i>Semisalsa contempta</i>	Faroje Spring	13/12/81
216	S	<i>Theodoxus jordani</i> <i>Melanopsis praemorsa buccinoidea</i>	Kufr Lahi Spring	13/12/81
217	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i>	Sofla Spring	13/12/81
218	St	<i>Physella acuta</i> <i>Lymnaea natalensis</i>	Wadi Amrawa Irbid	7/4/82
219	Sw	<i>Physella acuta</i>	Al-Hashra Bridge Swamps-Irbid	18/4/82
220	Sw	<i>Physella acuta</i> <i>Lymnaea natalensis</i> <i>Valvata saulcyi</i> <i>Bithynia philalensis</i>	Al-Hashra Swamps	18/4/82
221	St	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i>	Wadi Al-Rmemin Al-Rmemin	19/5/82
222	St	<i>Melanopsis praemorsa buccinoidea</i>	Wadi Al-Wala Madaba	17/3/82
223	S	<i>Melanopsis praemorsa costata</i> <i>Physella acuta</i> <i>Lymnaea natalensis</i> <i>Semisalsa contempta</i> <i>Pseudamnicola gaillardotii</i> <i>Pseudamnicola</i> sp. <i>Gyraulus piscinarum</i>	Ein om Ershid Irbid	29/3/82
224	S	<i>Melanopsis praemorsa buccinoidea</i>	Ein Al-Safayneh Saham-Irbid	27/4/82
225	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i>	Sultan Spring	
226	S	<i>Melanopsis praemorsa buccinoidea</i>	Sahal Spring NW Kufr Soum	12/6/82
227	St	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i>	Wadi Alal Irbid	12/6/82
228	S	<i>Theodoxus macrii</i> <i>Melanopsis praemorsa buccinoidea</i>	Al-Ghadir Springs N Kufr Soum	12/6/82
229	S	<i>Theodoxus jordani</i> <i>Lymnaea truncatula</i> <i>Gyraulus piscinarum</i>	Quaibeh Spring Hartha	12/6/82
230	S	<i>Theodoxus macrii</i>	Sheeha Spring Alal Wadi Area	12/6/82
231	S	<i>Theodoxus jordani</i> <i>Melanopsis praemorsa buccinoidea</i>	Abdou Spring	12/5/82



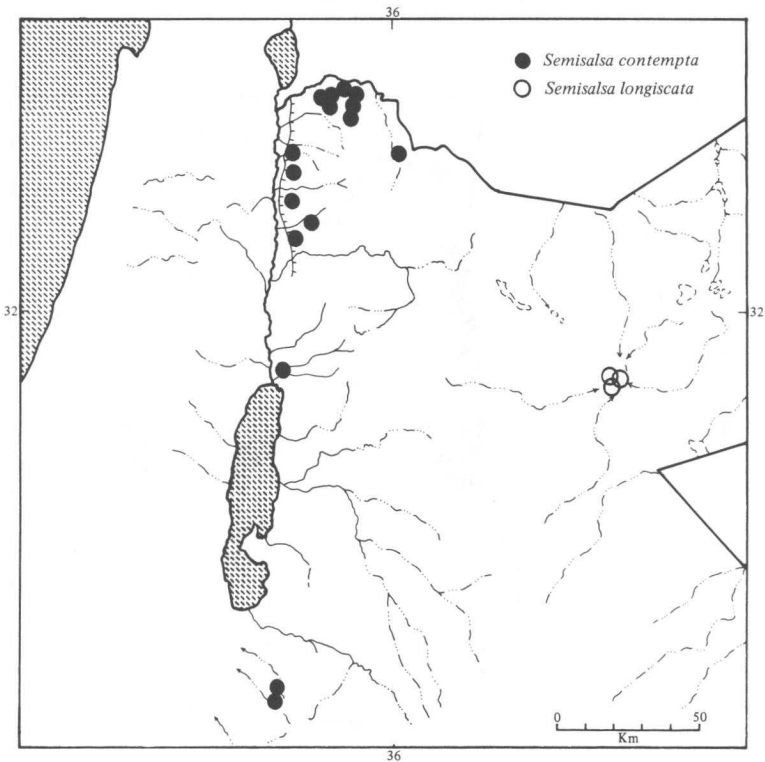
MAP 2. Distribution of *Theodoxus jordani* in Jordan.



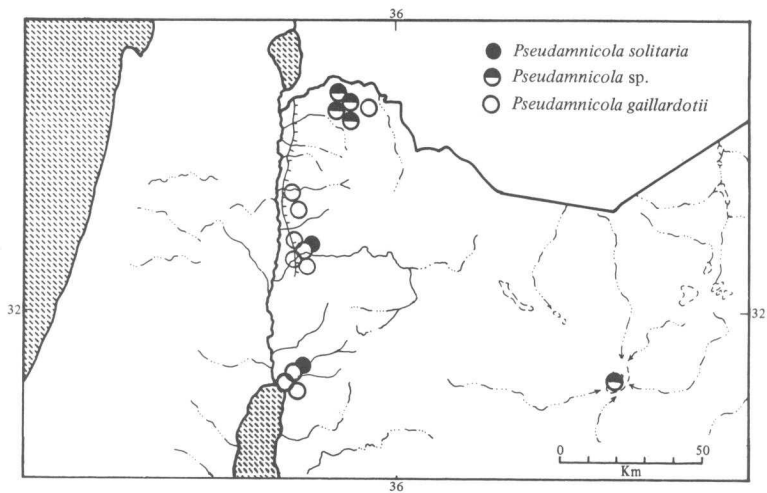
MAP 3. Distribution of *Theodoxus macrii* in Jordan.



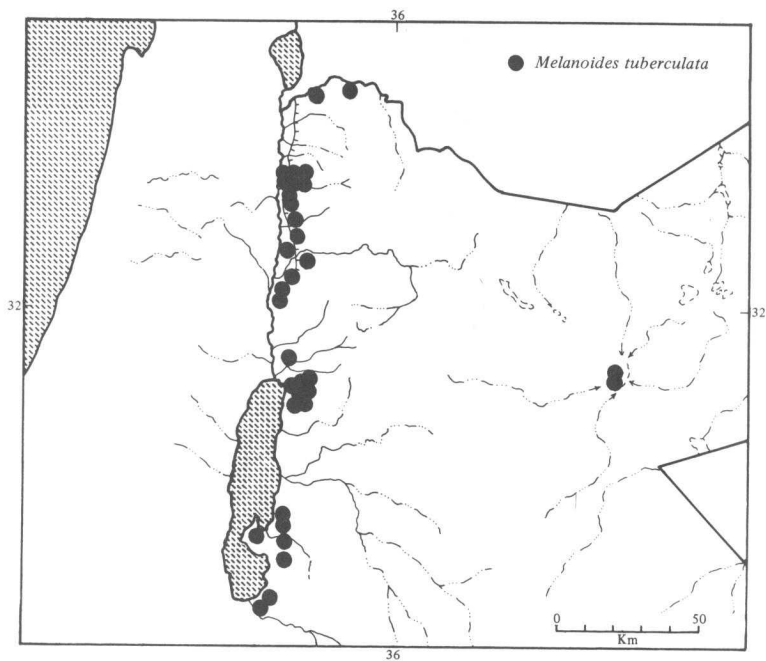
MAP 4. Distribution of *Valvata saulcyi* (○) and *Bithynia philalensis* (●) in Jordan.



MAP 5. Distribution of *Semisalsa longiscata* (○) and *Semisalsa contempta* (●) in Jordan.

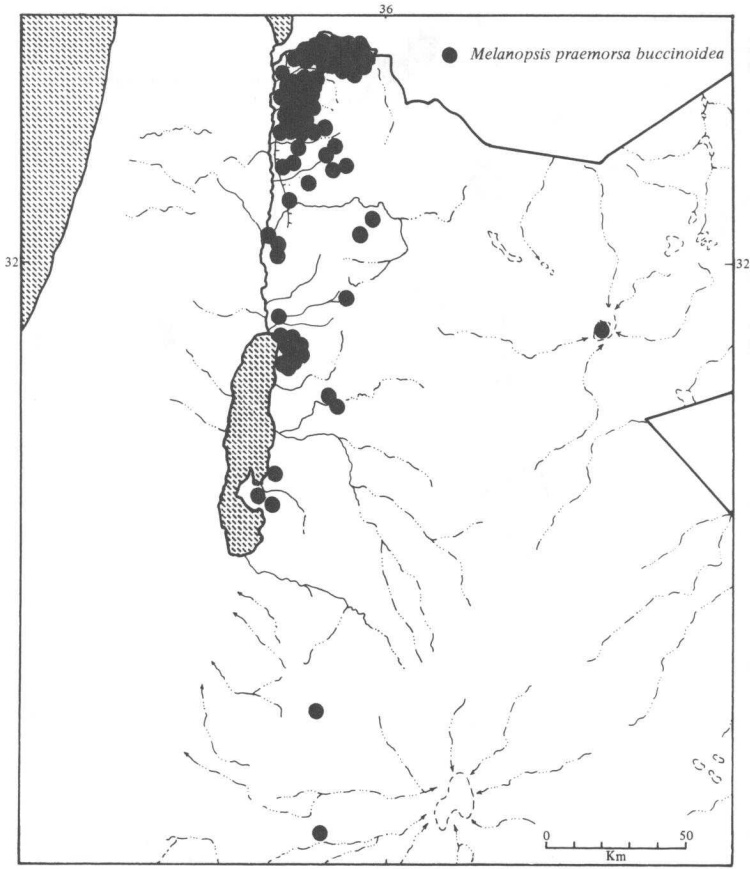


MAP 6. Distribution of *Pseudamnicola gaillardotii* (○), *Pseudamnicola solitaria* (●) and *Pseudamnicola* sp. (◐) in Jordan.

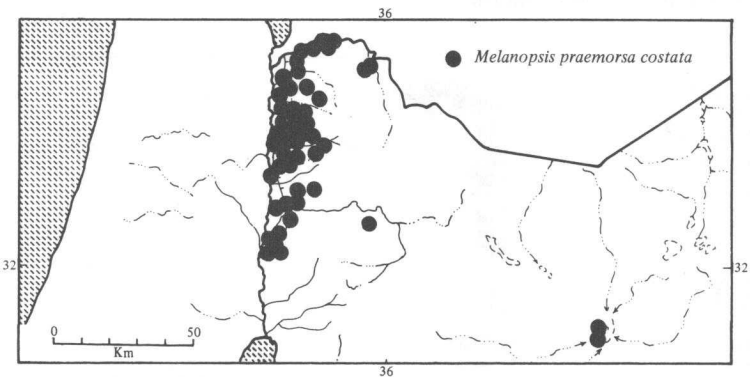


MAP 7. Distribution of *Melanoides tuberculata* in Jordan.

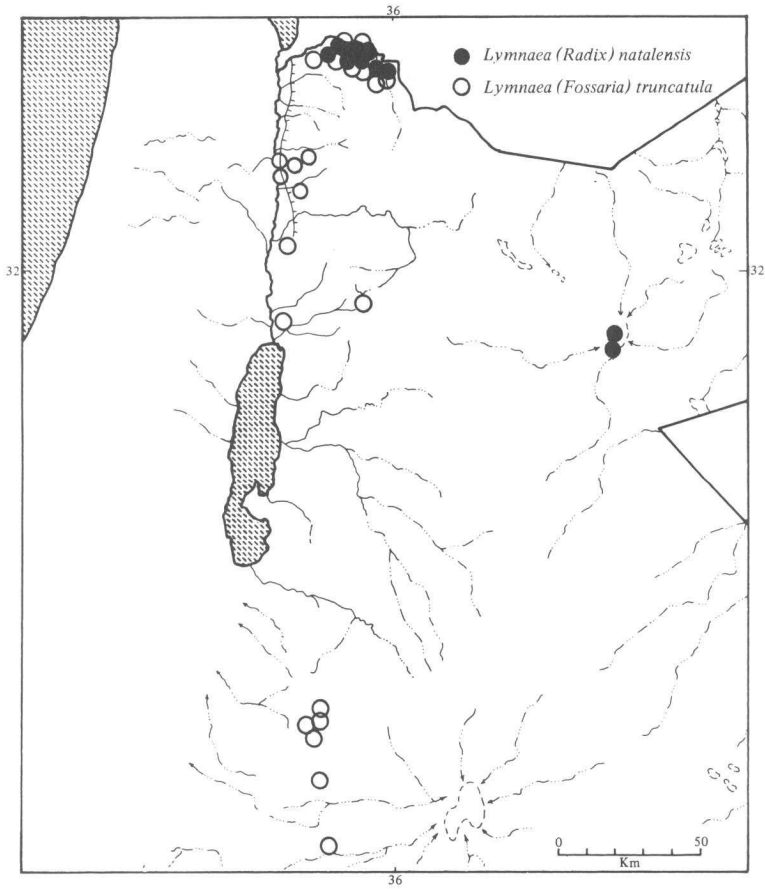




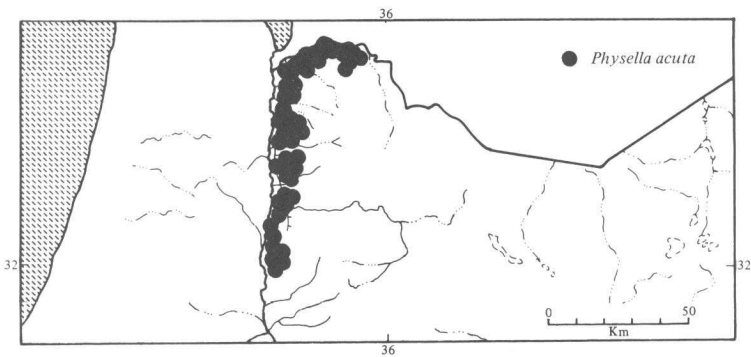
MAP 8. Distribution of *Melanopsis praemorsa buccinoidea* in Jordan.



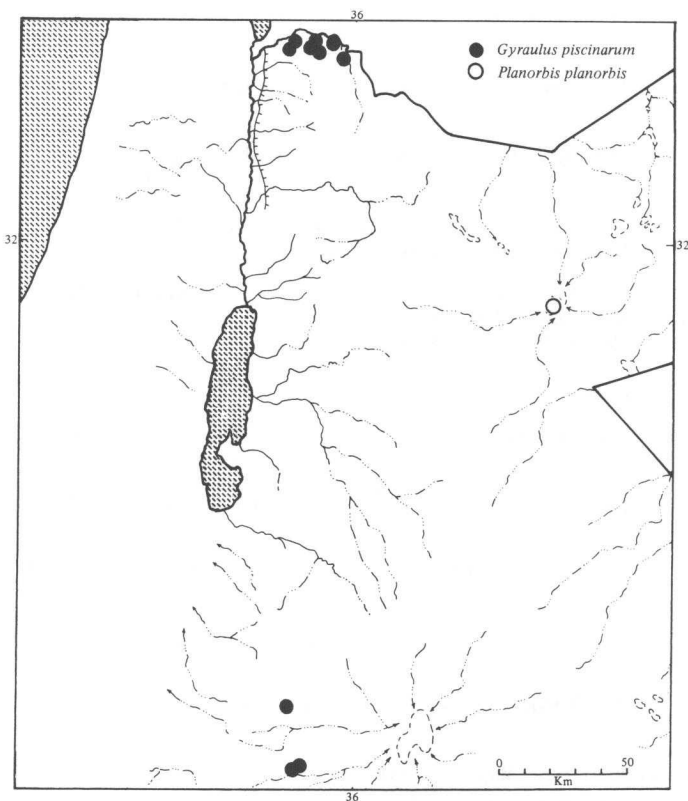
MAP 9. Distribution of *Melanopsis praemorsa costata* in Jordan.



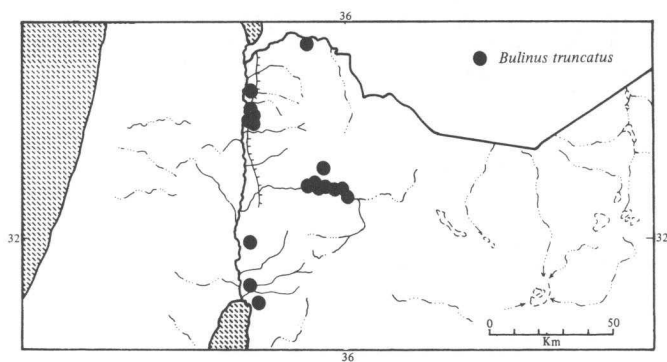
MAP 10. Distribution of *Lymnaea (Radix) natalensis* (○) and *Lymnaea (Fossaria) truncatula* (●) in Jordan.



MAP 11. Distribution of *Physella acuta* in Jordan.



MAP 12. Distribution of *Planorbis planorbis* (○) and *Gyraulus piscinarum* (●) in Jordan.



MAP 13. Locations where *Bulinus truncatus* has been found in Jordan. These sites were subjected to snail control measures (mainly mollusciciding).

232	S	<i>Lymnaea natalensis</i>	Om Khlal Spring Aqraba-Irbid	12/5/82
233	St	<i>Melanopsis praemorsa costata</i> <i>Physella acuta</i>	Wadi Al-Khour W Al-Mashare	4/3/82
234	S	<i>Melanopsis praemorsa buccinoidea</i>	Kfair Spring E Kufr Soum	
235	St	<i>Melanopsis praemorsa buccinoidea</i> <i>Melanopsis praemorsa costata</i>	Al-Rumman	
236	S + Sw	<i>Theodoxus jordani</i> <i>Melanoides tuberculata</i> <i>Melanopsis praemorsa buccinoidea</i> <i>Physella acuta</i> <i>Bulinus truncatus</i>	Zour Al-Hamam	10/3/82
237	C1	<i>Physella acuta</i>	Al-Jbarat Alla	6/7/80
238	S	<i>Gyraulus piscinarum</i>	Gahdir Spring Ma'an	28/8/82
239	S	<i>Pseudamnicola gaillardotii</i>	Al-Ma'alaka Springs, Ruwaita	3/3/81

## List 2. Freshwater Snails of Jordan and Their Distributions

*Theodoxus jordani* (p. 29; Map 2, p. 158)

15, 22, 28, 68, 78, 119, 155, 157, 158, 159, 173, 201, 202, 204, 205, 206,  
216, 229, 231, 236

*Theodoxus macrii* (p. 30; Map 3, p. 158)

2, 4, 5, 10, 13, 23, 32, 38, 45, 47, 56, 57, 59, 65, 67, 70, 72, 73, 78, 91, 92,  
94, 97, 98, 99, 100, 109, 115, 117, 118, 120, 128, 132, 136, 137, 139, 145,  
146, 151, 161, 166, 175, 184, 185, 187, 190, 191, 192, 203, 208, 209, 210,  
211, 212, 217, 221, 225, 227, 228, 230

*Valvata saulcyi* (p. 31; Map 4, p. 159)

220

*Bithynia philalensis* (p. 33; Map 4, p. 159)

65, 155, 159, 176, 197, 220

*Semisalsa longiscata* (p. 34; Map 5, p. 159)

37b, 39, 155

*Semisalsa contempta* (p. 35; Map 5, p. 159)

1, 81, 82, 84, 90, 108, 114, 135, 149, 153, 167, 169, 172, 174, 196, 215, 223, 232

*Pseudamnicola gaillardotii* (p. 36; Map 6, p. 160)

1, 9, 10, 42, 80, 83, 135, 180, 189, 223, 239

*Pseudamnicola solitaria* (p. 36; Map 6, p. 160)

1, 135

*Pseudamnicola* (?) sp. (p. 37; Map 6, p. 160)

38, 165, 176, 193, 223

*Melanoides tuberculata* (p. 38; Map 7, p. 160)

2, 3, 4, 9, 10, 11, 12, 14, 18, 21, 22, 24, 26, 28, 29, 38, 65, 78, 93, 112, 116, 118, 119, 127, 129, 141, 142, 143, 145, 146, 147, 148, 155, 178, 236

*Melanopsis praemorsa buccinoidea* (p. 40; Map 8, p. 161)

2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 23, 43, 44, 46, 47, 48, 49, 50, 53, 55, 57, 58a, 58b, 59, 60, 63, 64, 66, 67, 69, 70, 71, 72, 73, 75, 76, 77, 78, 87, 89, 91, 92, 94, 97, 98, 99, 100, 102, 104, 106, 109, 112, 113, 115, 117, 118, 120, 122, 123, 125, 126, 127, 128, 130, 131, 132, 134, 136, 137, 139, 140, 144, 145, 146, 151, 155, 157, 161, 163, 167, 168, 173, 174, 176, 177, 178, 180, 181, 182, 183, 184, 185, 188, 190, 191, 192, 195, 196, 198, 203, 206, 207, 208, 209, 210, 211, 212, 213, 216, 217, 221, 222, 224, 225, 226, 227, 228, 231, 234, 235, 236, 22

*Melanopsis praemorsa costata* (p. 41; Map 9, p. 161)

15, 16, 19, 23, 24, 27, 29, 31, 32, 34, 35, 38, 43, 45, 51, 55, 57, 65, 67, 68, 72, 74, 78, 83, 88, 92, 94, 99, 100, 102, 104, 109, 115, 116, 118, 119, 120, 121, 124, 127, 128, 132, 133, 136, 137, 139, 155, 158, 159, 201, 202, 203, 204, 205, 206, 223, 233, 235

*Lymnaea (Radix) natalensis* (p. 43; Map 10, p. 162)

40, 155, 164, 165, 171, 186, 199, 218, 220, 223, 232

*Lymnaea (Fossaria) truncatula* (p. 44; Map 10, p. 162)

14, 85, 99, 101, 117, 149, 150, 151, 152, 154, 156, 162, 167, 170, 174, 176, 177, 194, 205, 206, 214, 229

*Physella acuta* (p. 46; Map 11, p. 162)

14, 15, 16, 17, 19, 20, 21, 22, 24, 25, 28, 29, 30, 31, 32, 33, 34, 36, 41, 45, 52, 54, 61, 62, 68, 78, 79, 83, 86, 88, 94, 95, 96, 101, 103, 105, 107, 108, 109, 110, 111, 112, 114, 116, 118, 119, 127, 128, 129, 133, 138, 159, 160, 165, 171, 176, 177, 179, 186, 193, 197, 199, 200, 205, 218, 219, 220, 223, 233, 236, 237

*Planorbis planorbis* (p. 48; Map 12, p. 163)

37a

*Gyraulus piscinarum* (p. 49; Map 12, p. 163)

154, 156, 162, 175, 176, 187, 193, 223, 229, 238

*Bulinus truncatus* (p. 51; Map 13, p. 163)

65, 95, 107, 127, 236. Because they contained *Bulinus truncatus*, these sites were subjected to various control measures (mainly mollusciciding). Additional localities (those found before or after the main snail survey) for *Bulinus truncatus* are: Muthalath Al-Masri (Saliba et al., 1976), Roman pools at Jarash (Saliba & Salameh, 1981), King Talal Dam impoundment, Taha Spring, Twaheen Al-Edwan near the Zarka River, Mahrab Abu Ahmed in the Jordan Valley, and, most recently, Kafreen Dam in the Jordan Valley and Om Khlal Spring near the Yarmouk River (sites 14 and 232, respectively, in the previous snail survey).

## 11. Ecology

### I. Freshwater Habitats in Jordan

Jordan has a wide diversity of freshwater aquatic habitats, the majority of which support, or are capable of supporting, small populations. Such habitats include most flowing and standing aquatic ecosystems except for the Dead Sea, its adjacent saline lowlands, certain occasionally flowing seasonal water courses and some thermal springs which may have high concentrations of toxic minerals. The various aquatic habitats can be classified as either standing or flowing waters which may be permanent or seasonal.

#### Flowing Waters

##### Springs

Springs are naturally occurring sources of surface water that emerge from groundwater reserves, collected from the infiltration of rain water or snow melt at higher elevations. Springs will emerge when these reserves intercept permeable groundlevel. The proximity of the spring to its ultimate site of infiltration is dependent upon local geology. Small mountain springs (Fig. 77) and many springs in the Ghor discharge water collected within a few kilometers of the outflow. These may be seasonally variable in the volume of water discharged. The more constant high volume springs such as Druze Azraq or Ein Nimreh have sources from large aquifers whose recharge areas may lie hundreds of kilometers away. Springs may have shallow groundwater sources or may be supplied by water from deep in the earth's crust. The temperature and chemical composition of the geological formations through which it flows determine the quality of the emergent spring water.

##### Mineral-water Springs

Warm mineral springs are examples of waters emerging after contact with hot volcanic formations. These springs frequently have high dissolved solid contents. Hamma springs in the northern part of the country, Ein Nimreh near Zarqa (Figs. 78-80), and Hammamat Ma'in in the mountains east of the Dead Sea are examples of geothermal springs.

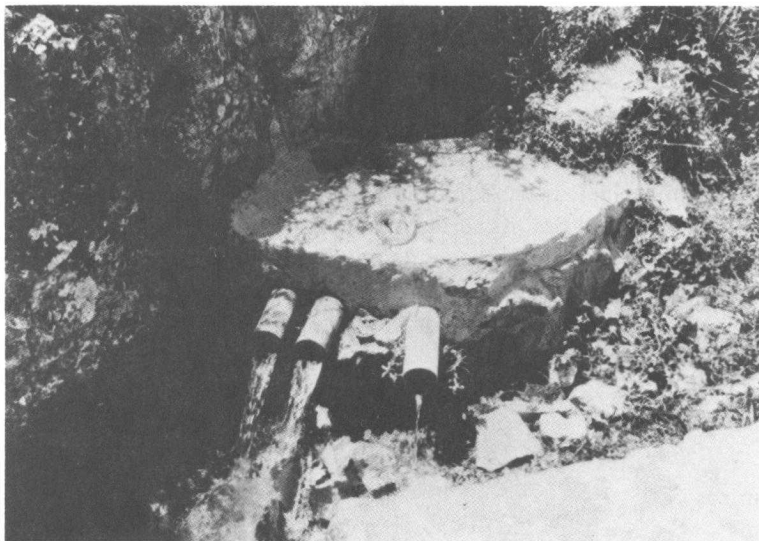


FIG. 77. A mountain spring, with a small concrete retainer at the source.

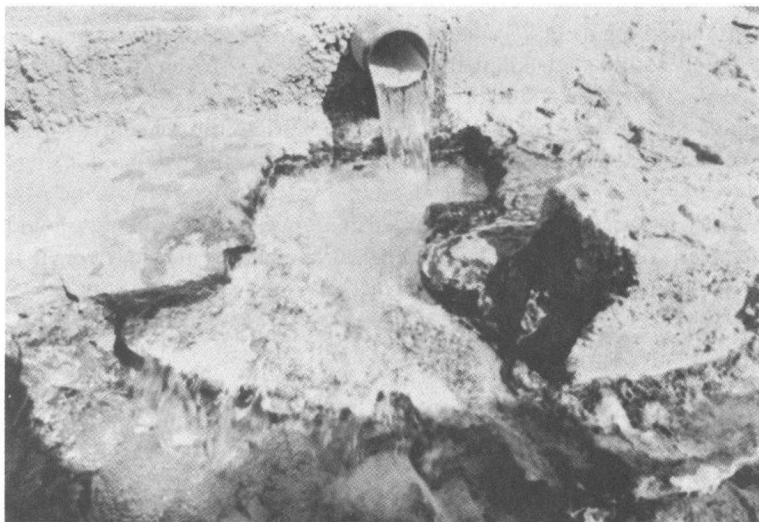


FIG. 78. Warm mineral-water spring (capped).





FIG. 79. Large surface deposits of sulphur from the warm mineral-water spring shown in Fig. 78.

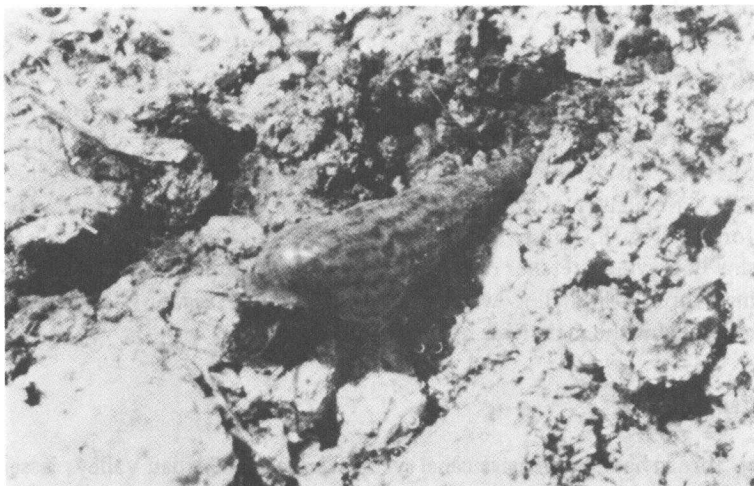


FIG. 80. A live snail (*Melanoides tuberculata*) crawling in the warm sulphurous water from the mineral-water spring shown in Fig. 78.

### Artesian Wells

Deep-bored wells from which water flows up like a fountain because of internal pressure, or due to mechanical pumping, are called artesian wells. Frequently, water is transported from artesian wells in open concrete or earthen conduits (Fig. 81).

### Streams

Streams (Figs. 82-84) are defined here as naturally occurring flowing waterbodies which move down an elevational gradient in a defined channel. Streams are seasonally variable in flow, bottom contour and vertical gradient. Streams frequently consist of stretches of shallow riffles and deeper pools which provide a variety of mixed habitats. They are smaller than rivers and are generally less than 10 meters wide and 30 centimeters deep. Those which receive water principally from surface runoff of precipitation are seasonal or intermittent and, at times, may retain water only in pools. Streams which receive water from springs or groundwater seepage are more permanent and flow throughout the year. Wadi Jaresh, Wadi Yabis and Wadi Mujib are examples of streams. Some flows, such as that of Wadi Fidan, may discharge their water back into permeable soils.

### Rivers

Rivers are large, permanent, slowly flowing bodies of water which carry a considerable volume between gradually sloping, well-defined banks frequently confined within a broader floodplain or zour. The Jordan (Fig. 85) and the Yarmouk are typically defined as rivers. In slowly flowing stretches of rivers, snails may be found in pools, on floating debris, or in shallow water at the river margins (Fig. 86). Snails may also inhabit the main river bed in shallow depths.

### Canals

Jordan has an extensive canal system serving the Jordan Valley; lesser canal systems are located in other regions. Primary canals, such as the East Ghor Canal (Figs. 87, 88), take water from primary water sources at higher elevations to the general area where the water is to be distributed. Smaller, secondary canals (Fig. 89) take water to the vicinity of



FIG. 81. A capped artesian well at Qualiba spring (near Irbid) with a concrete conduit for transporting its water.



FIG. 82. Small stream running into the Jordan River.



FIG. 83. Stream at Wadi Araba.



FIG. 84. Small seepage stream at Ma'an.



FIG. 85. The Jordan River near the Shaik Hussain Bridge.

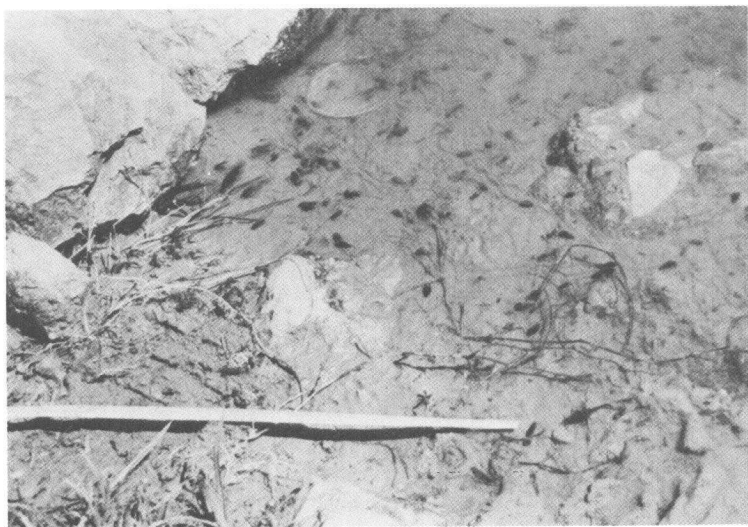


FIG. 86. Snails (mostly *Melanopsis*) in shallow water at the margin of the Jordan River at Shaik Hussain Bridge.

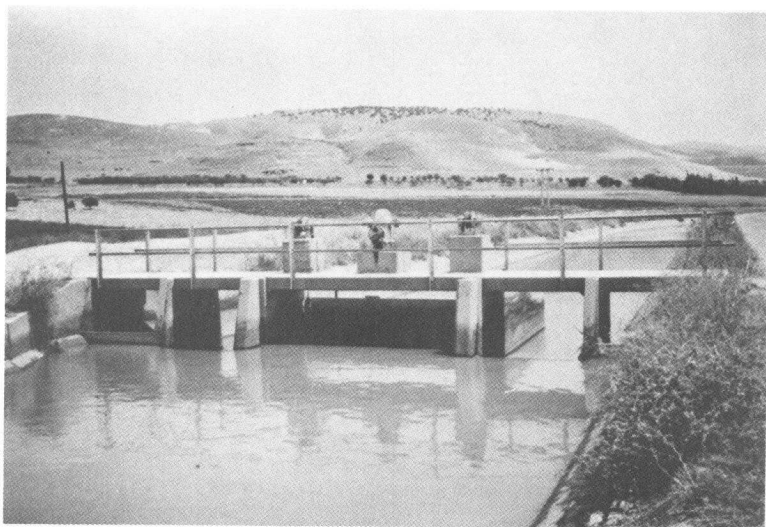


FIG. 87. The East Ghor Canal near Al-Mashareh.

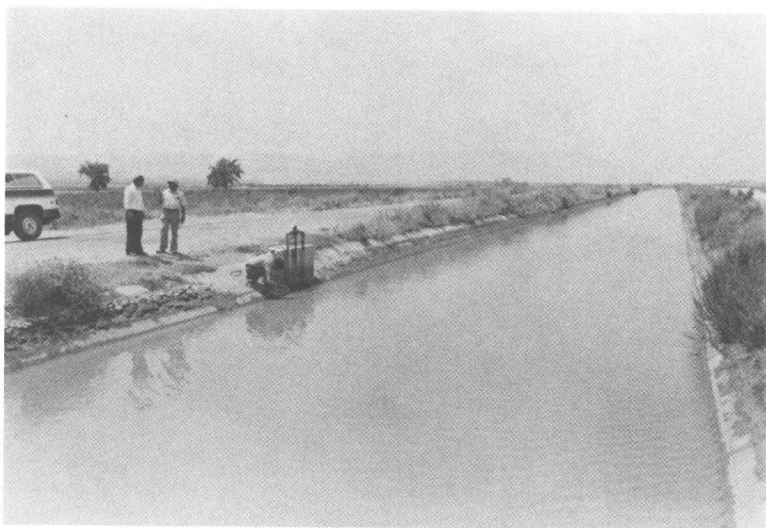


FIG. 88. The East Ghor Canal near Al-Mashareh.



FIG. 89. A secondary canal near Al-Mashareh taking irrigation water from the East Ghor Canal to the vicinity of agricultural fields.



FIG. 90. Earth-lined tertiary canals at Al-Mansheith taking irrigation water to fields under cultivation.



the fields to be irrigated. Tertiary canals (Fig. 90) distribute the water to the fields. The quaternary canals (Fig. 91) are used within the fields for delivery of water to crops. The primary canals generally have a constant flow of water and deliver water to the secondary canals on a periodic schedule which may allow occasional drying. The tertiary canals are also controlled by the Jordan Valley Authority and are frequently dried, but residual water may be held in depressions of these canals. The quaternary canals are generally mud ditches dug by individual farmers and may have residual water or saturated mud bottoms and sides.

Other small, privately operated canal systems are located near Jarash in Wadi Jarash and along the upper Zarqa River. The canals in this area may distribute water pumped from lower elevations and stored in excavated cisterns for distribution.



FIG. 91. Tertiary canals at Al-Mansheih taking water to cultivated fields and quaternary canals within the fields.

### Standing Waters

#### Impoundments or Dam Reservoirs

These are bodies of water confined by a barricade (or "dam") which



prevents the normal flow of water. The dam is usually built across the valley of a river or wadi and causes water to collect from the normal stream flow or from rainfall. There are five existing dams in Jordan, the largest of which is the King Talal Dam (Figs. 92, 93) on the highland of the Jarash area. The other dams are located in the Jordan Valley; these are the Kafreen Dam and the Shaib Dam, the Ziglab Dam and the newly constructed Wadi Al-Arab Dam.

Dam reservoirs may harbor snail populations in areas of the impoundment where the substratum is favorable or in areas where floating debris may collect. In some areas, such as Africa, the impounded waterbody may be referred to as a "dam".

### Ponds

A pond is a body of standing water that is smaller than a lake. Ponds are of various types and may be either natural or man-made. Natural ponds are often associated with springs (Figs. 94, 95).

### Pools

Pools may be either natural or man-made (Figs. 96, 97). Natural pools may result when ground depressions collect water during the wet season and, as such, they are the same as one type of "pond". Other natural pools are associated with springs. Man-made pools are constructed to hold water for bathing (Fig. 97), drinking or other household uses, and may be lined with earth, stone or concrete.

### Swamps

Swamps are areas of land saturated with water, and may be partially, periodically or continuously covered with water. Such areas occur in the lowlands near the Jordan and Yarmouk rivers, and an extensive swamp is associated with Azraq Oasis (Figs. 98, 99), fed by waters issuing from the Azraq springs. Swamps typically support a characteristic vegetation which includes tamarix, phragmites and typha.

### Zour

"Zour" is the Arabic term for the lowland beside a river which gets filled with water during the flooding season. The English-language term for zour is "flood plain".



FIG. 92. King Talal Dam.



FIG. 93. A portion of the impounded water behind the King Talal Dam.

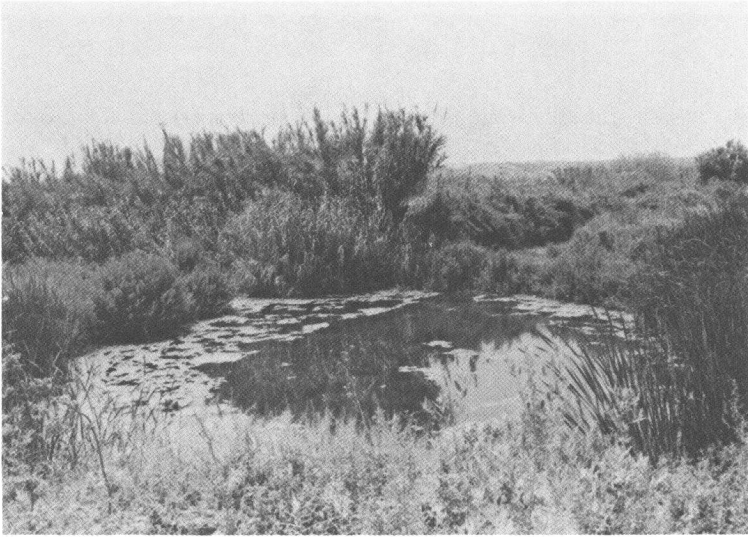


FIG. 94. A spring pond at Shaik Hussain spring. The water from this spring drains into the Jordan River, about 500 meters away. Before being molluscicided, this habitat contained live *Bulinus truncatus* and other snails. *Physella acuta* has now invaded the recently sterile water.

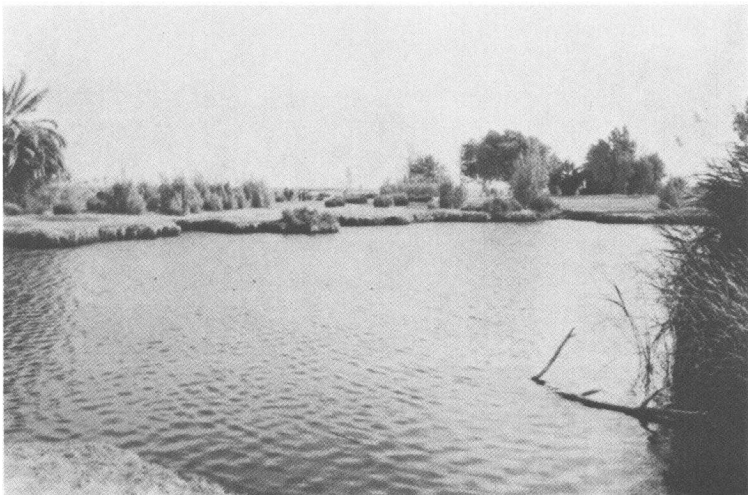


FIG. 95. A spring pond at Druze Azraq.



FIG. 96. A barrow pit, near Azraq.

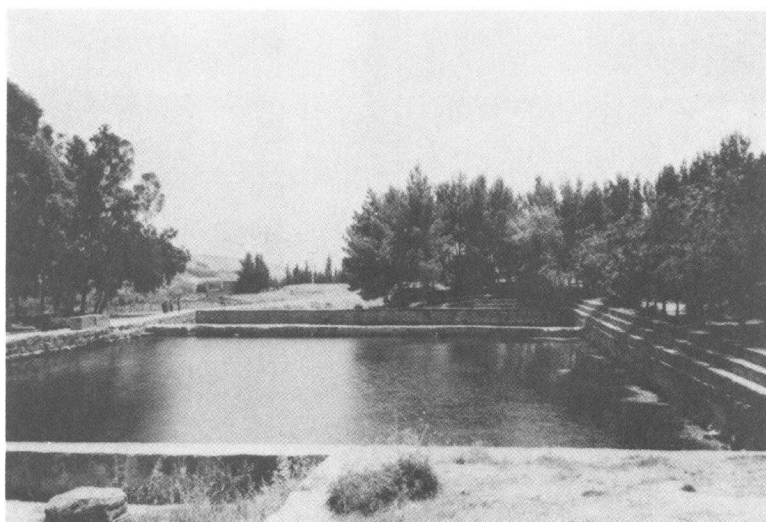


FIG. 97. The Roman pool at Jarash, constructed in ancient times for bathing. Because the pool was found to be infested with *Bulinus truncatus*, it has now been drained.

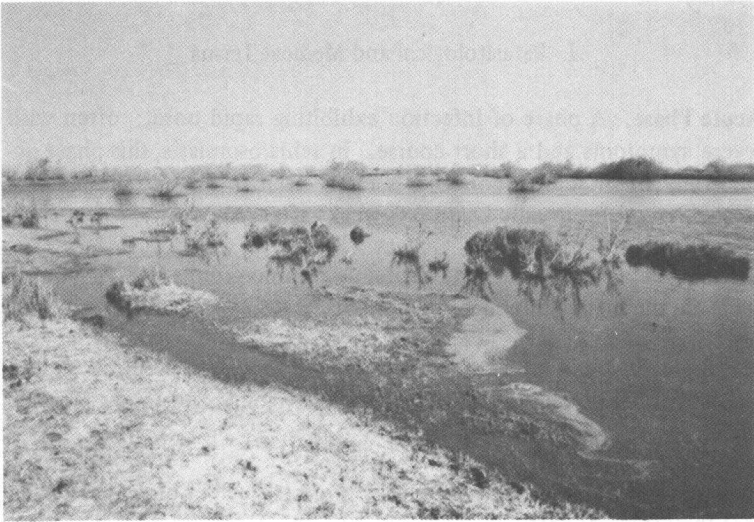


FIG. 98. Swamp area associated with Azraq Oasis, during winter (low-water period).



FIG. 99. Swamp area associated with Azraq Oasis, during winter (low-water period).

## 12. Glossary

### J. Parasitological and Medical Terms

**Acute Phase.** A phase of infection exhibiting rapid onset; often with severe symptoms and a short course. In schistosomiasis, this phase occurs only on first infection and is rarely seen in established endemic areas. Symptoms usually begin 3-8 weeks after exposure.

**Amino Acid.** An organic acid containing amino groups ( $\text{NH}_2$ ). Amino acids are the main component of proteins.

**Anaphylaxis.** An exaggerated response to a foreign protein by an animal which has already been immunologically sensitized to that foreign body.

**Anastomosis.** The union of branches or parts, such as blood vessels, so that they interconnect.

**Anastomotic veins.** Anastomosis between mesenteric and spinal veins which allows both worms and eggs to reach ectopic sites such as the central nervous system, where granulomas forming around them may produce focal lesions.

**Antibody.** A soluble protein substance formed in response to, and interacting specifically with, an antigen.

**Antigen.** A substance, usually a protein or carbohydrate, which when introduced into the body induces the production of an antibody.

**Anthelmintic treatment.** A treatment to get rid of parasitic worms, usually using drugs.

**Arteriole.** A tiny artery continuous with a capillary.

**Arteriolitis.** An inflammation of an arteriole.

**Ascites.** The accumulation of serous fluid in the peritoneal cavity.

**Asexual reproduction.** Reproduction of an individual from cell division, budding, or some other method, but not from the union of sex cells.

**Bilharziasis** [Bilharzia]. Another name for schistosomiasis (see p. 189).

**Biological transmission.** A condition in which the organism that transmits the causative agent of a disease plays an essential role in the life history of a parasite.

**Biopsy.** The excision of a small piece of living tissue for microscopic examination in order to establish a diagnosis of a disease or pathological condition.

**Brevifurcate cercaria.** A cercaria with a short, forked tail.

**Buffer.** A substance that is capable of neutralizing, within limits, both acids and bases in a solution and functions to maintain the original hydrogen-ion concentration (pH) of that solution; a substance that provides resistance to change in pH on the addition of acid or base.

**Capillaries.** Minute blood vessels, averaging 0.008 mm in diameter, that connect arterioles with venules.

**Carbohydrate.** A major class of animal foods formed of carbon, hydrogen and oxygen and produced mostly by green plants.

**Cercaria** (plural: cercariae). A free-swimming larva of a trematode parasite that is produced by a sporocyst or a redia in a parasitized mollusk. See Fig. 1, p. 7.

**Cercarial dermatitis.** The inflammation of the skin accompanied by itching, redness and sometimes skin lesions and caused by penetration of humans by cercariae of nonhuman schistosomes.

**Ciliated.** Having microscopic hairlike processes (cilia).

**Colic.** A spasm in any hollow or soft tubular organ, accompanied by pain.

**Complement.** A complex series of enzymatic proteins in normal serum that combine with antigen-antibody complex.

**Complement fixation test (CFT).** An immunological procedure to test the presence of antibodies using a known antigen (or *vice versa*). The

ability of an antigen to fix or bind complement (or *vice versa*) indicates the presence of the antibody in question.

**Contraindication.** Any symptom or circumstance indicating the inappropriateness of a form of treatment otherwise advisable.

**Contralateral.** Affecting the opposite side of the body.

**Cor pulmonale.** Heart disease caused by pulmonary hypertension secondary to disease of the blood vessels of the lung. The pathology of pulmonary schistosomiasis may show granuloma formation and fibrosis in the lungs, leading to blockage of finer pulmonary circulation, arteriolitis with increasing pulmonary blood pressure, and dilation and hypertrophy of the right ventricle leading to right heart failure.

**Cysticercosis.** The occurrence of a cystic stage of tapeworms in man and domestic animals that results from ingestion of parasitic eggs.

**Daughter sporocyst.** A larval form in the life cycle of trematode parasites, consisting mainly of a germinal sac containing germ balls which give rise to cercariae.

**Defecate.** Evacuation of the bowels.

**Dermatitis.** Inflammation of the skin.

**Diarrhea.** The frequent passage of an abnormally watery bowel content. Diarrhea is a frequent symptom of a gastro-intestinal disturbance and is most often the result of increased peristalsis.

**Digenetic trematode.** Any fluke that requires a definitive host (usually a vertebrate animal) and at least one intermediate host (a mollusk) to complete its life cycle.

**Echinostome cercaria.** A type of cercaria that can be distinguished by a simple tail and a collar of spines around its anterior end.

**Ectopic.** Located away from the normal position.

**Efficacy.** The capacity of a drug to produce the desired effect.

**Embryo.** The early developmental stage of any organism.



**Embryocidal.** Any agent that is destructive to the embryo.

**Endemic.** A relatively steady moderate level of infection or disease in the human population.

**Eosinophilia.** A condition exhibiting accumulation of an unusual number of eosinophils (a granular leukocyte with cytoplasmic inclusion that readily stains red with the acid, eosin) in the blood.

**Epidemiology.** The field of medical science which is concerned with the relationship of the various factors and conditions which determine the frequencies and distribution of an infection process, a disease or a physiological state in a human community.

**Epileptiform.** A form of seizure exhibiting a similarity to epilepsy.

**Erythema.** A spot on the skin showing diffused redness.

**Esophageal varix** (plural: esophageal varices). A tortuous dilation of a vein in the esophagus.

**Fibrosis.** An abnormal formation of fibrous tissues.

**Fistula.** An abnormal tubelike passage from a normal cavity or tube to a free surface or to another cavity; may be congenital due to incomplete closure of parts or may result from abscesses, injuries or inflammatory processes.

**Gastro-intestinal.** Relating to both the stomach and the intestine.

**Granuloma.** A focal accumulation of cells, usually lymphoid and epithelioid cells, which occurs in various infectious diseases.

**Gynecophoric canal.** A longitudinal canal on the ventral surface of a male schistosome in which the female is held during copulation.

**Haematuria.** The occurrence of blood in the urine.

**Hemorrhoidal plexus.** A mass of dilated, tortuous veins in the anorectum, involving the external and internal venous plexuses of the area.

**Hepatosplenic involvement.** Enlargement of the liver and spleen brought

about by infection (as with *Schistosoma mansoni*).

**Hermaphrodite.** An organism possessing genital and sexual characteristics of both sexes.

**Hydronephrosis.** The collection of urine in the renal pelvis due to obstructed outflow, leading to distention and atrophy of the organ.

**Hypertension.** A condition in which the patient has a higher blood pressure than normal.

**Immunodiagnostic method.** Any diagnostic procedure used to establish the presence of antibodies against a particular antigen.

**In vivo.** Occurring in the living organism.

**Incubation period.** a) Biologic incubation — related to the development of the parasite and is terminated as soon as the parasite or its products can be demonstrated in the feces or other excreta, or in the circulating blood by aspiration, biopsy or other diagnostic procedures. b) Clinical incubation — interval between exposure and the earliest evidence of symptoms produced as a result of the infection.

**Indirect hemagglutination (IHA).** An immunological procedure in which erythrocytes are treated with tannic acid and antigens absorbed to their surface and used to test for the presence of an antibody. Agglutination of erythrocytes indicates a positive result.

**Induration.** A hardening of an organ or a tissue, often as a result of fibrosis.

**Inferior mesenteric veins.** The blood vessels that collect venous blood from the lower region of the intestine.

**Intermediate host.** A host in which the parasite undergoes larval or juvenile development.

**Interscapular.** Region between the two shoulder blades.

**Intestinal schistosomiasis.** An infection or a disease characterized by the presence of adult schistosome worms (for example, *Schistosoma mansoni*) in the mesenteric veins, with the eggs produced by the worms

penetrating the intestinal wall and passing out of the human body in the feces.

**Intradermal.** Intracutaneous; within the dermis of the skin.

**Intradermal reaction.** The reaction in the skin caused by the injection of an antigen or other substance.

**Lactation.** The production of milk in animals.

**Larva** (plural: larvae). The newly hatched stage of any of the various animals that differ markedly from the adult form.

**Lateral spine.** A pointed structure projecting from one side of the egg near (but not at) the end, which is a diagnostic feature of *Schistosoma mansoni* egg shells. See Fig. 55, p. 122.

**Life cycle.** The successive stages in the ontogenetic development of an organism from the egg through larval stage(s) to adult parasitic forms requiring one or more hosts. See Fig. 1, p. 7.

**Longifurcate cercaria.** A cercaria with a long, forked posterior tail end.

**Lyophilize.** To freeze a substance (organ, tissue, blood, serum) rapidly using a very low temperature and then dehydrating it in a high vacuum.

**Malaise.** A feeling of discomfort, uneasiness or indisposition, often indicative of infection.

**Malignant.** Tending to become progressively worse, resisting treatment and resulting in death.

**Metacercaria.** The encysted form of a cercaria.

**Miracidium** (plural: miracidia). The ciliated free-swimming larva of a digenetic trematode. To continue development, the miracidium must penetrate a snail of a particular species, in which the miracidium metamorphoses into a sporocyst. See Fig. 1, p. 7.

**Morbidity.** State of being diseased.

**Mother sporocyst.** A larval form of a digenetic trematode which consists of a germinal sac containing germinal cells which develop into daughter sporocysts. The mother sporocyst is formed by the metamorphosis of a miracidium after it has penetrated a snail.

**Mucosa.** A membrane lining passages and cavities, communicating with the air and histologically consisting of an epithelial surface layer, a basement membrane and an underlying connective tissue layer called the lamina propria.

**Necrosis.** The death of a portion of an animal tissue, differentially affected by loss of blood supply, local lesions caused by an infectious agent, or by any other local injury.

**Neoplasm.** A new, abnormal tissue formation or tumor that grows at the expense of the healthy organism.

**Outpatient.** A sick or diseased individual who remains on treatment at a hospital or clinic without being hospitalized.

**Pathology** (adjective: pathological). The study of the nature and cause of diseases which involve changes in structure and function.

**Perineum.** The external region between the vulva and anus in a female or between the scrotum and anus in a male.

**Periportal cirrhosis.** A chronic disease of the liver, caused by eggs of schistosomes being swept back to the liver with the portal blood flow, and which lodge in the finer branches of the portal system, characterized by formation of dense periportal connective tissue and increased resistance to blood flow through the liver due to vascular obstruction.

**Peristalsis.** A progressive involuntary wavelike movement that occurs in hollow tubes (for example, the intestine) of the body.

**Polyp.** A tumor with a pedicle commonly observed in vascularized organs.

**Portal blood.** The blood reaching the liver from the intestines.

**Precipitation technique.** A process whereby a substance is separated from a solution by action of a reagent that brings about precipitation or agglutination.

**Proctoscope.** An instrument used for rectal inspection.

**Protein.** An essential constituent of living cells of plants and animals that is composed of amino acids.

**Pseudotubercles.** Granulomatous reaction around schistosome eggs in the liver, bladder wall or intestinal wall.

**Pulmonary hypertension.** A pathology caused by, for example, pulmonary schistosomiasis, characterized by increased pressure in the pulmonary arterial system.

**Pus.** A liquid product of inflammation composed of albuminous substances, a thin fluid and leucocytes.

**Pyelitis.** An inflammation of the renal pelvis and its calices.

**Pyelonephritis.** An inflammation of the kidney substance and pelvis.

**Pyonephrosis.** Discharge of pus and accompanying destruction of kidney tissue, with total or almost complete loss of kidney function.

**Pyrogen.** A fever-causing agent.

**Radio-immunological technique.** A sensitive method of determining the concentration of substances, particularly of protein-bound hormones in blood plasma; the procedure is based on competitive inhibition of binding of radioactively labelled hormones to a specific antibody.

**Schistosome.** A blood fluke (Class Trematoda; Family Schistosomatiidae), which as an adult worm lives in a blood vessel or visceral organ and produces eggs which are either trapped in various internal organs, or discharged with feces or urine.

**Schistosomiasis.** A helminthic infection caused by blood flukes belonging to the genus *Schistosoma* which affects primarily the liver and spleen, intestine or urinary bladder, and, in cases of severe infections, lungs and other visceral organs.

**Schistosomula.** An immature schistosome in the body of a definitive host. It is formed by cercaria that has penetrated the skin of its host and has lost its tail.

**Serology** (adjective: serological). The scientific study of serum, which is the watery portion of the blood after coagulation.

**Side effect.** The undesirable effect of a drug, for example, like nausea, headache or insomnia.

**Sinus** (plural: sinuses). An open space in an organ or body.

**Skin test.** A sensitivity test for the diagnosis of a protozoan or helminthic diseases, performed by the injection of antigen into the skin. A positive immediate test is indicated by the formation of a wheal and a surrounding erythematous zone within 30 minutes from the time of injection.

**Splenomegaly.** Enlargement of the spleen.

**Sporocyst.** The stage in the life history of a trematode worm usually found in tissues of the first intermediate host, a mollusk. It is essentially a germinal sac containing germ cells which give rise to daughter sporocysts or rediae. See Fig. 1, p. 7.

**Submucosa.** A layer of loose connective tissues underneath a mucous membrane richly provided with a network of blood vessels.

**Supernatant fluid.** A clear fluid remaining at the top of a container after settling of a precipitate.

**Swimmer's itch.** A form of dermatitis in humans caused by penetration of cercariae of nonhuman schistosome species.

**Tenesmus.** A spasmodic contraction of the anal or the vesicular sphincter, accompanied by pain and persistent desire to empty the bowel or bladder, and, yet, unproductive.

**Terminal spine.** A pointed projecting structure on the end of a *Schistosoma haematobium* egg shell, the placement of which distinguishes the egg from a *Schistosoma mansoni* egg. See Fig. 55, p. 122.

**Toxemia.** The distribution throughout the body of poisonous substances of bacteria, or other infectious agents, growing in a localized site and producing generalized symptoms.

**Trematode** (synonym: fluke). A member of the animal class Trematoda, a group of parasitic flatworms. All trematodes are ectoparasitic or endoparasitic, and possess well-developed adhesive organs or suckers.

**Tumor.** A spontaneous new growth of tissue forming an abnormal mass or enlargement.

**Ulcer.** An open sore of the skin or mucous membrane.

**Uremia.** A toxic condition associated with impaired or abnormal functioning of the kidney. The condition is produced by the retention of nitrogenous substances in the blood that are normally excreted by the kidney.

**Urinary schistosomiasis.** An infection caused by *Schistosoma haematobium*, a blood trematode whose adult worms live in the small blood vessels around the urinary bladder. The eggs pass through the walls of the urinary bladder, causing tissue damage.

**Urology** (adjective: urological). A field of medicine concerned with the study of the urinary tract of both male and female and the genital tract in the male.

**Vena cava.** The principal vein that collects venous blood from the upper and lower regions of the body and empties the blood into the right auricle of the heart.

**Venous blood.** Blood flowing within veins.

**Venule.** A tiny vein continuous with a capillary.

**Viable.** Capable of living.

**Viability.** The ability to survive or continue growing and developing.

**Wheal.** An elevation on the skin surface, often accompanied by itching or burning sensation and characterized by a white center and a reddish periphery.

**Worm load.** The number of parasites (adults and larvae) carried by a particular host.

**Xiphidiocercaria.** A cercaria with a boring stylet near the mouth.

## K. Malacological Terms

**Adventitious.** Occurring in an unusual place, as the brood pouch in thiarid snails.

**Albino.** An animal (for example, a snail) with a congenital deficiency of pigment in the skin, eyes, etc.; lacking pigment.

**Angular, angulate.** Having an angle (or having the tendency to form an angle), rather than a round contour (see Fig. 63,b, p. 125).

**Aperture.** The opening or "mouth" of a snail shell through which the headfoot protrudes when the snail is active (see Fig. 58, p. 123).

**Apex** (plural: apexes or apices). The tip of a gastropod shell farthest from the aperture (see Figs. 57, 58, p. 123).

**Apophysis** (plural: apophyses). A calcareous protruberance or elongate structure, such as that on the inner side of a neritid operculum (see Fig. 2,b, p. 29). It normally consists of two pieces, a short and stout "peg" and a longer and narrower "rib".

**Auricle.** A chamber of the heart that receives blood from blood vessels and passes it to a ventricle.

**Axial.** Parallel to the axis or columella, i.e., transverse to the direction of the shell's spiral coil.

**Axis.** The fundamental central line of a structure or body, as, for example, the columella of a shell (see Fig. 58, p. 123).

**Base.** The part of the shell opposite to the apex. When a shell is held with the apex directed upward, the base is the "bottom" part of the shell. In regard to the natural position of the shell as carried by the snail, the "base" is the anterior end (see Figs. 57, 58, p. 123).

**Bipectinate.** Having two margins furnished with outwardly projecting parallel filaments, like the teeth of a double-sided comb (see the gill in Fig. 26,a, p. 54).

**Bithyniid.** A common-name adjective referring to a member of the family Bithyniidae (p. 32).



**Body whorl.** The last complete whorl or volution of a spiral snail shell, measured from the outer lip back to a point immediately above the outer lip (see Fig. 58, p. 123). It is normally the largest whorl of the shell, and is called the body whorl because it encloses the greatest part of the snail's body.

**Breathing pore** (pulmonary opening; pneumostome). The opening through which air or water passes to and from the lung in pulmonate snails (see Fig. 71,a, p. 127).

**Brood pouch.** A sac-like cavity in the body of a female snail in which eggs or embryos are placed and develop.

**Bulinine.** A common-name adjective referring to a member of the planorbid subfamily Bulininae (p. 50).

**Calcareous, calcified.** Composed of carbonate of lime (calcium carbonate).

**Callus.** A layer of calcareous material on a shell secreted by the snail's mantle.

**Chitinized.** To become hardened with a chitin-like substance.

**Class.** A higher taxonomic category or group between the order and phylum in the hierarchy of animal classification. Each class contains one or more orders. The living mollusks are divided into seven classes, the Gastropoda (snails, slugs, limpets, etc.), Bivalvia or Pelecypoda (clams, mussels, oysters, etc.), Scaphopoda (tusk and tooth shells), Aplacophora (solenogasters), Monoplacophora, Polyplacophora (chitons) and Cephalopoda (squid, cuttlefish, octopusses).

**Classification.** The arrangement of different kinds of organisms into groups, reflecting relationships, and the groups into a scheme or system, usually hierarchial in nature.

**Clockwise.** The direction of rotation of the hands of a clock when viewed from the front as the hands move forward.

**Coil.** A single loop of a circular, spiral turn. To follow a circular, spiral direction.

**Color bands.** Revolving spiral stripes of a darker hue or different color from the ground or background color which occur on some species of gastropod shells.

**Columella.** The internal column around which the whorls revolve; the axis of a spiral shell.

**Columellar lip.** The apertural margin at the columellar region of a coiled snail shell (see Fig. 58, p. 123).

**Conchological.** Referring to a mollusk shell (derived from “conch”, meaning “shell”). (Conchology is the study of, or a treatise on, mollusk shells.)

**Concentric.** Having the same center, for example, the nucleus, and expanding outward in parallel (that is, equidistant) lines, as in the lines of growth of an operculum (see Fig. 72,c, p. 128).

**Conical.** Shaped like a cone, that is, tapering evenly from a wide, circular base to a point (see Fig. 61, p. 125).

**Constricted.** Narrowed; compressed; being divided into equal or unequal halves by a groove or depression.

**Corneous.** Resembling horn or consisting of horn-like material.

**Counter-clockwise.** In the direction opposite to the rotation of the hands of a clock when viewed from the front as the hands move backward.

**Deflected.** Bent downward from the natural plane of growth, as in the terminal part of the last whorl in some snail shells.

**Depressed.** Flattened dorso-ventrally or postero-anteriorly, as the spire of a shell, where the spire of the shell is very short in relation to the last or body whorl (see Fig. 60,d, p. 124).

**Depressed conic (widely conic).** Designation for a snail shell with a spire angle of about  $100^{\circ}$  ( $\pm 5^{\circ}$ ) (see Fig. 61,h, p. 125).

**Dextral.** Wound or spiraled to the right, i.e., with a clockwise spiral.

When the shell aperture faces the observer and the shell apex is directed upward, the aperture is on the right (see Fig. 62,b, p. 125).

**Digitation.** A finger-shaped elongation or protuberance.

**Discoidal.** Round and flat like a disc (see Fig. 60,e, p. 124).

**Elongate.** Lengthened; extending lengthwise; especially higher than wide (see Fig. 60,a,b, p. 124).

**Elongately conic.** Designation for a snail shell with a spire angle of about  $30^{\circ}$  ( $\pm 5^{\circ}$ ) (see Fig. 61,b, p. 125).

**Entire.** Refers to the lip of a shell that forms a complete circle or oval, that is, the lip is not interrupted by a space where it meets the parietal wall of the body whorl.

**Evaginate.** To turn inside out.

**Family** (adjective: familial). A taxonomic group of genera sharing certain basic features that set them off from other such groups of genera. The family is a level of classification between the genus and the order. Names of families end in *-idae*.

**Fauna.** All of the animals peculiar to a particular region, area or country, or to a particular geological time period.

**Flattened.** Deviating from being round and approaching a flat surface. Commonly used to describe shell whorls that diverge from an evenly rounded contour (see Fig. 63,d, p. 125).

**Form.** A particular variation or aggregate of variations within a population. The terms "form" or "forms" have some utility in discussing interpopulational variations, but a "form" has no formal standing in our system of zoological nomenclature.

**Genitalis** (plural: genitalia). An organ of reproduction, especially the organ used in coitus.

**Genus** (plural: genera; adjective: generic). A basic category of biological classification above the species level which contains (usually) two or

more related species which share certain features. A few genera are monotypic, that is, contain only one species.

**Gill.** A specialized outgrowth of the body wall which functions in respiration by providing a large surface area underlaid with an abundant blood supply, thereby facilitating rapid oxygen-carbon dioxide exchange between the ambient environment and the body fluids.

**Glassy.** Like glass; transparent and shiny.

**Globose, globular.** Spherical; approaching a globe or sphere in shape (for example, see Fig. 60,c, p. 124).

**Globosely conic.** Designation for a snail shell with a spire angle of about  $80^{\circ}$  ( $\pm 5^{\circ}$ ) (see Fig. 61,g, p. 125).

**Glossy.** Smooth and shining; highly polished.

**Growth lines.** Minute lines on the outer shell surface indicating minor rest periods during growth (see Fig. 69, p. 127). Not to be confused with the major "rest marks" or varices, caused by prolonged growth arrest (as during winter).

**Headfoot.** The combined head and foot organ of a snail. The foot (the snail's locomotory organ) anteriorly is in close proximity to and not separated from the snail's head (see Fig. 57,a, p. 123).

**Helicoid.** In the form of a low three-dimensional spiral; with a somewhat depressed spire and whorls that increase regularly in diameter (for example, see Fig. 60,d, p. 124).

**Hemispherical.** Formed like a half sphere.

**Hemocoel.** An expanded cavity of the circulatory system which surrounds various of the snail's internal organs.

**Hemocyanin.** A blood pigment similar to hemoglobin, but containing copper instead of iron. Like hemoglobin, its function is to bind oxygen for use in respiration. Hemocyanin is the respiratory pigment found in nearly all mollusks.

**Hemoglobin.** The red iron-containing pigment of blood which functions

to bind oxygen for use in respiration. In mollusks, hemoglobin is very rare, but it is characteristic of the freshwater pulmonate snail family Planorbidae (p. 47).

**Hermaphrodite.** An animal, such as a pulmonate snail, having both male and female reproductive systems in the same body.

**Hermaphroditism.** The condition of having both male and female reproductive systems in the same individual.

**High spired.** A shell in which the smaller whorls protrude above (or behind, in the natural position; see Fig. 57, a, p. 123) the larger last or body whorl (in contrast to a discoidal shell (see Figs. 17 (p. 47) and 60, e (p. 124)) in which the spire whorls are even with the body whorl, or are inverted below its margins.

**Horn.** The color of cow's horn. Consisting of horn-like material.

**Hydrobiid.** A common-name adjective referring to a member of the family Hydrobiidae (p. 33).

**Imperforate.** Refers to a spiral snail shell which has no opening or external cavity at its base (see Fig. 66, a, p. 126). In such a case, the inner sides of the coiled whorls are appressed, leaving no cavity, or, if they are not appressed and a cavity is formed, then its opening is completely covered by a callus or the reflected columellar apertural lip.

**Impressed.** Rather deeply indented; sunken distinctly below the general surface (see Fig. 64, b, p. 126).

**Inverted.** Turned inward; in a reversed position from normal.

**Keel.** A prominent ridge; a carina.

**Large** (in reference to shell size). A term used to refer to a snail shell that is more than 30 mm in length or diameter (see Fig. 59, p. 124).

**Limnophile.** A common-name adjective referring to a member of the order Limnophila (p. 42).

**Limpet.** A snail with a low, conical, unspiraled (or nearly so) shell.

**Lip.** Edge of the aperture of a shell (see Fig. 58, p. 123).

**Lumen.** The cavity of a tubular structure or organ.

**Lymnaeid.** A common-name adjective referring to a member of the family Lymnaeidae (p. 42).

**Major diameter.** The widest diameter of a snail's shell, as measured from the outer apertural lip on one side of the shell to the outer edge of the body whorl opposite the aperture on the other side of the shell.

**Mantle.** The skin covering the viscera of a mollusk. Also called pallium. It normally lies next to and under the shell, and secretes the shell.

**Mantle cavity.** A space between the mantle and the body of a mollusk, which typically contains the gills and into which discharge the mollusk's reproductive products and excretory and alimentary wastes.

**Mantle collar.** The edge of the mantle, often thickened, which lies next to and under the apertural lip of a snail's shell.

**Marginal teeth.** Teeth at the lateral margins of a molluscan radula which differ in shape from the teeth in the central area of the radula.

**Medium** (in relation to shell size). A term (see Fig. 59, p. 124) used to refer to a snail shell that is 10 mm or more but less than 30 mm in length (or in diameter, if the longest dimension of the shell is its width).

**Melanin.** Black pigment.

**Minute** (in regard to shell size). A term (see Fig. 59, p. 124) used to refer to a snail shell that is less than 2 mm in length (for an elongate shell) or width (for a depressed shell that is wider than high).

**Mollusk** (mollusc). A member of the phylum Mollusca, one of the major groups or phyla of animals, which includes the snails and slugs, chitons, clams and oysters, tooth and tusk shells, squids and octopusses, etc.

**Multispiral.** Refers to an operculum in which there are numerous, very slowly enlarging spirals, coils or whorls (Fig. 72,a, p. 128).

**Narrowly conic.** Designation for a snail shell with a spire angle of about

20° ( $\pm 5^\circ$ ) (see Fig. 61,a, p. 125).

**Narrowly subovately conic.** Designation for a snail shell with a spire angle of about 40° ( $\pm 5^\circ$ ) (see Fig. 61,c, p. 125).

**Neritid.** A common-name adjective referring to a member of the family Neritidae (p. 28).

**Neritiform.** The shape common to a member of the snail family Neritidae, that is, subglobose or hemispherical, with few rapidly enlarging whorls, very reduced spire, and a heavily calloused and expanded parietal apertural margin (see Figs. 2, 3, pp. 29, 30).

**Nodule.** A small rounded node, knot, lump or irregularly shaped mass, such as the projections occurring on the shell surface of some snails (see Fig. 69, p. 127).

**Non-planate.** Not flattened; having an everted spire (high spired), in contrast to the flattened or inverted spire of the shell of the discoidal (planate) Planorbidae.

**Nuchal lobe.** A lobe on the right side of the headfoot of bithyniid snails.

**Nuclear whorls.** The whorls of a snail shell that are formed by the embryo in the egg case before hatching; the embryonic whorls. These whorls often have a different appearance from the whorls formed by the snail after hatching (see Fig. 58, p. 123).

**Nucleus.** The first-formed (earliest) part or beginning of a shell or operculum (for example, see Fig. 72,d, p. 128).

**Opaque.** Not emitting light; neither translucent nor transparent.

**Operculum** (plural: opercula). A corneous or calcareous plate borne on the dorsal posterior foot of prosobranch snails which closes the aperture when the snail withdraws into its shell (see Fig. 70, p. 127).

**Order** (adjective: ordinal). A higher taxonomic category or group between the family and class in the hierarchy of animal classification. Each order contains a group of families related to one another by common morphological characteristics.

**Osphradium** (plural: osphradia). An olfactory (chemical detecting) sense organ of many mollusks.

**Outer lip.** That part of the shell's apertural lip that is opposite the parietal lip or wall (see Fig. 58, p. 123).

**Oval, ovate.** In the shape of the longitudinal section of a hen's egg, that is, oblong and curvilinear, with one end narrower than the other.

**Ovately conic.** Designation for a snail shell with a spire angle of about  $60^{\circ}$  ( $\pm 5^{\circ}$ ) (see Fig. 61, e, p. 125).

**Oviducal gland.** A gland arising from the oviduct in most female snails which provides nutriment to the eggs prior to spawning.

**Oviparous.** Producing eggs; egg-laying.

**Pallial.** Pertaining to the molluscan pallium or mantle.

**Parietal.** Pertains to the inside wall of the shell aperture, that is, the wall closest to the columella (see Fig. 58, p. 123).

**Parthenogenetic.** The condition whereby a female animal, for example, a female snail, can produce eggs that hatch and develop without being fertilized by sperm.

**Paucispiral.** Refers to an operculum in which there are few rapidly enlarging spirals, coils or whorls (see Fig. 72, b, p. 128).

**Peg.** The shorter and stouter part of the two pieces composing the apophysis on the inner surface of the operculum of the Neritidae. The longer and narrower projection is called the "rib" (see Fig. 2, b, p. 29).

**Penis sheath.** In pulmonate snails, a muscular sheath or tube that envelops the penis during periods of reproductive inactivity.

**Perforate.** Refers to a spiral gastropod shell which has a very narrow perforation at its base, formed where the inner sides of the coiled whorls do not join.

**Periphery.** The edges of a shell as seen in outline.



**Phallate.** In the form of, or shaped like, a phallus.

**Physid.** A common-name adjective referring to a member of the family Physidae (p. 45).

**Plait.** A fold on the columella in some snail species, caused by the twisting of the columella (see Fig. 67,a, p. 126).

**Planate.** Flattened; flattened on both sides, that is, without an everted spire; the form of the shell in the discoidal Planorbidae (see Fig. 17 (p. 47); Fig. 60,e (p. 124)).

**Planorbid.** A common-name adjective referring to a member of the family Planorbidae (p. 47).

**Preputium.** A part (a muscular tube) of the penial structure of a freshwater pulmonate snail. It is distal to the penis and penis sheath when the snail is not copulating. During copulation, the preputium everts so that the penis is at its distal end.

**Prosobranch.** A common-name adjective referring to a member of the subclass Prosobranchia (p. 27).

**Pseudobranch.** A "false" or secondarily derived gill; a vascularized outgrowth near the opening to the pulmonary cavity (pneumostome) of aquatic pulmonate snails which aids in respiration (see Fig. 41, p. 57). Not a true gill.

**Pulmonate.** A common-name adjective referring to a member of the subclass Pulmonata (p. 41).

**Race.** A geographically or ecologically isolated group of individuals or populations that differ in one or more characters from other individuals or populations of the same species in other locations; a subspecies.

**Radula** (plural: radulae). A rasp-like structure in the mouth of all mollusks except the bivalves (clams and their relatives) which is used to scrape off food during feeding. The radula consists typically of a number of longitudinal and transverse rows of minute sharp "teeth", each with one or more cutting blades or "cusps".

**Rhipidoglossan radula.** A type of prosobranch radula with rows of numerous narrow hooked teeth radiating out like sections of a fan. This

type of radula is characterized especially by its large number of marginal teeth.

**Rib.** A transverse elevation or ridge of considerable size on the surface of a shell; costa (see Fig. 69, p. 127). In regard to the operculum of the Neritidae, the rib is the longer and narrower part of the two pieces composing the apophysis on the inner opercular surface.

**Rimate.** Refers to a coiled gastropod shell that has at its base a narrow "umbilical" opening that is partially closed by the expansion of the anterior columellar lip (see Fig. 66,c, p. 126).

**Reflected.** Turned back, as the apertural lip in some snail shells (see Fig. 68,c, p. 126).

**Sclerotized.** Hardened.

**Sculpture.** The natural surface markings, other than those of color, usually found on snail shells, and often furnishing identifying marks for species recognition (see Fig. 69, p. 127).

**Sensu lato** (abbreviated *s. lat.* or *s. l.*). A Latin phrase meaning "in the broad sense".

**Sensu stricto** (abbreviated *s. str.* or *s. s.*). A Latin phrase meaning "in the strict (for narrow) sense".

**Shallow.** Having little depth; hardly or little indented (for example, see Fig. 64,a, p. 126).

**Shell.** The hard outside covering of most mollusks (see Fig. 57, p. 123), produced by the mantle and composed primarily of calcium carbonate crystals deposited in an organic matrix. In snails, the shell is usually coiled, and it provides characters for species identification and classification.

**Shouldered.** Refers to the appearance (in outline) of the posterior outer peripheral part of a whorl that is sharply rounded in contrast to the more even curvature of the rest of the shell (see Fig. 63,c, p. 125).

**Sinistral.** Wound or spiraled to the left, that is, with a counter-clockwise spiral. When the shell aperture faces the observer and the shell

apex is directed upward, the aperture is on the left (see Fig. 62,a, p. 125).

**Sinus.** A recess, indentation or embayment.

**Siphonal canal.** A tubular extension of the anterior aperture of some prosobranch snail shells which encloses the siphon. A siphonal canal is especially characteristic of the prosobranch order Neogastropoda.

**Small** (in reference to shell size). A term (see Fig. 59, p. 124) used to refer to a snail shell that is more than 2 mm in length (or diameter for a shell with a depressed spire), and less than 10 mm.

**Species** (plural: species; adjective: specific). A taxonomic group comprising the same "kinds" of closely related individuals potentially able to breed with one another, and unable to breed with other "kinds".

**Spindle-shaped.** Fusiform; shaped like a spindle, that is, with a relatively thick middle and tapered to a point at both ends.

**Spines.** Sharp, pointed projections extending outwardly from the surface of some snail shells (see Fig. 69, p. 127).

**Spiral.** Winding, coiling or circling around a central axis; winding around a fixed point and continually receding from it; the form of the shell of most shells.

**Spiral sculpture.** Surface markings of a snail shell which pass continuously around the whorls more or less parallel to the suture (see Fig. 69, p. 127).

**Spire.** The whorls of a snail shell, excepting the last or body whorl (Fig. 58, p. 123). The spire is measured as the distance (parallel to the columella) from the suture where the apertural lip meets the body whorl to the shell apex.

**Striation.** A spiral incised line on the surface of a snail shell (see Fig. 69, p. 127). Also used, less precisely, for a fine spiral raised line, or for a fine transverse line.

**Stylet.** A small, hard, pointed process or part.

**Subclass.** A higher taxonomic category or group between the order and class in the hierarchy of animal classification. Subclasses are used when it is necessary to divide a class into more than one group of orders. In the class Gastropoda (snails, slugs, limpets), the subclasses are the Prosobranchia (gill breathers; gills anterior to the heart), Opisthobranchia (generally gill breathers; gills, when present, posterior to the heart) and Pulmonata (lung breathers).

**Subfamily** (adjective: subfamilial). A taxonomic category or group between the genus and family in the hierarchy of animal classification. Subfamilies are used when it is necessary to divide a family into more than one group of closely related genera. The subfamily is therefore a subordinate category to the family. Each subfamily contains one or more genera. Names of subfamilies end in *-inae*.

**Subgenus** (plural: subgenera; adjective: subgeneric). A taxonomic category or group between the species and the genus in the hierarchy of animal classification. Subgenera are used when it is necessary to divide a genus into more than one group of closely related species. The subgenus is therefore a subordinate category to the genus. Each subgenus contains one or more species.

**Subglobose.** Nearly globular or spherical in shape.

**Subglobosely conic.** Designation for a snail shell with a spire angle of about  $70^{\circ}$  ( $\pm 5^{\circ}$ ) (see Fig. 61,f, p. 125).

**Subovately conic.** Designation for a snail shell with a spire angle of about  $50^{\circ}$  ( $\pm 5^{\circ}$ ) (see Fig. 61,d, p. 125).

**Subspecies** (plural: subspecies; adjective: subspecific; synonym: race). One or more populations of a species which inhabit a distinct geographic area and which share morphological features setting them off from other populations of the species.

**Suture.** The line on the shell surface where two adjoining whorls meet (see Fig. 64, p. 126).

**Synonym.** One of two or more different names for the same species, genus, etc. In zoological nomenclature, the older name for any particular taxon has precedence.

**Taxon** (plural: taxa). Any taxonomic group, for example, a race, or a subspecies, species, genus, family, order, etc.

**Taxonomy** (adjective: taxonomic). The practice, study, methodology, science, etc., of dealing with kinds of organisms.

**Tentacle**. One of a pair of slender, flexible organs on the head of snails used for feeling. Freshwater snails each have one pair of tentacles, with an eye at the base of each tentacle (see Figs. 57, 70, 71, pp. 123, 127).

**Thiarid**. A common-name adjective referring to a member of the family Thiaridae (p. 38).

**Tooth**. 1. A short, usually high, callus or deposit of shelly material in the aperture of some shells. 2. A small, sharp, blade-like structure, duplicated many times in longitudinal and vertical rows, on a ribbon, which is used by a mollusk to scrape a food surface during feeding.

**Torsion**. The twisting during embryonic development of a snail of its upper body (visceral mass, mantle and mantle cavity, and shell) 180° counter-clockwise in relation to the lower body (headfoot). This twisted body is the most basic difference between snails and other mollusks.

**Translucent**. Partially transparent; allowing diffused light to be transmitted.

**Transparent**. Clear; transmitting light without scattering, so that structures lying beyond are clearly visible.

**Transverse**. At right angles to the spiral direction of the whorls; parallel to the columella or axis of the shell; in the same direction as (that is, parallel to) the growth lines of a snail shell (see Fig. 69, p. 127).

**Truncate**. Cut off at the end; terminating abruptly; ending in a transverse line (for example, see Fig. 67,c, p. 126).

**Umbilicate**. Refers to a spiral snail shell which has an opening or cavity at its base, and more specifically to one in which the opening is more than a very narrow perforation (see Fig. 66,d, p. 126). This cavity is formed in those shells in which the inner sides of the coiled whorls do not completely join.

**Umbilicus.** An opening or cavity in the center of the base of a snail shell which is formed when the inner sides of the coiled whorls do not completely join (see Fig. 66,d, p. 126).

**Unipectinate.** Having one margin furnished with outwardly projecting parallel filaments, like teeth of a comb.

**Uterine.** Pertaining to uterus, an enlarged portion of the oviduct in the female snail which serves for passage of eggs, or for the development of eggs or young.

**Whorl.** One complete turn or coil of a spiral snail shell (see Fig. 58, p. 123).

**Widely conic** (depressed conic). Designation for a snail shell with a spire angle of about  $100^{\circ}$  ( $\pm 5^{\circ}$ ) (see Fig. 61,h, p. 125).

**Zebrated.** Patterned in alternating dark and light stripes (for example, see Fig. 2, p. 29).

## L. Ecological Terms

**Abiotic components.** The nonliving factors, such as light, temperature, soil type, nutrients, etc., which are significant to an ecosystem.

**Algae** (singular: alga). Simple, frequently unicellular, plants which lack complex reproductive and transport systems. Algae are most commonly encountered in aquatic environments.

**Aquatic.** Living in water.

**Artesian well.** A deep-bored well from which water flows up like a fountain because of internal pressure or mechanical pumping.

**Bacteria** (singular: bacterium). Microscopic, unicellular organisms which lack chloroplasts or internal structures. Usually they range in size from 0.0005 mm to 0.05 mm. They are very diverse in form and habitat. Some species are pathogenic.

**Benthos** (adjective: benthic). Those organisms which live on or within the bottom substrata of an aquatic habitat.

**Biodynamics.** The study of the dynamics of reproduction and breeding of a certain population of animals during a certain period of time.

**Biological competitor.** A species which requires the same or very similar limited resources as another species, and by depriving the second species of adequate supplies of needed resources, it may reduce the growth or abundance of the second species.

**Brackishwater.** Natural water that is somewhat salty, but containing less salt than sea water.

**Breeding colony.** A population of a single species in an area which sustains reproductive activity.

**Breeding minima** (singular: breeding minimum). The lower extreme of a range of environmental variables at which an organism can successfully reproduce.

**Brine.** Water saturated with or having large quantities of salt.

**Cistern.** A man-made reservoir (usually a stone- or cement-lined excavation) for storing water.

**Community.** The assembly of plants and animals which interact as a group in a locality.

**Confluence.** The flowing together of two waterways to form a larger waterway.

**Dam.** A barricade built across a valley or wadi which prevents the normal flow of water and serves to collect water from the stream, or from rainfall. The term "dam" is sometimes also used for the impounded water. See Figs. 92, 93, p. 178.

**Dispersal avenue.** A way of distributing organisms from a center of origin to previously unpopulated outlying areas.

**Ecology.** The scientific study of those factors which influence the distribution and number of organisms.

**Eddy.** A current pattern in flowing water, characterized by a swirl of moving water which has been spun off from the major current flow.

**Effluent.** Water flowing out.

**Environment.** Those surrounding factors (biological and abiotic) which influence the success and abundance of organisms.

**Epidemiology.** The study of the dynamics of the spread of a disease in a population.

**Estivate.** To greatly reduce or suspend metabolic activity in order to survive desiccation.

**Flood plain.** The area adjacent to a river, which is formed by the erosion of the land by the river; this low-lying area usually is covered with water during flood season (an English-language equivalent of "Zour").

**Flotsam.** Floating debris.

**Focus** (plural: foci). A specific place at which an activity is centered, such as disease transmission.



**Grazing.** The act of an animal in consuming food (usually plant material) from the surface across which it is moving.

**Ground Water.** Water which is contained in the ground below the soil surface.

**Habitat.** The place or external environment in which an animal or plant lives.

**Habitat alteration.** The physical alteration of a habitat so as to modify its environment, thereby influencing the abundance or type of the organisms in the habitat.

**Host-parasite relationship.** The important interactions between a host and parasite which influence the survival and numbers of each.

**Hydrology.** The study of movement and quantity of natural waters.

**Hypersaline.** Naturally occurring salt concentration exceeding that of sea water (that is, salt in excess of 35 parts per thousand).

**Impoundment.** A body of water formed by the construction of a dam. See Figs. 92, 93, p. 178.

**Intermittent stream.** A stream which does not flow during all seasons, but is subject to drying during periods of drought.

**Intrinsic rate of natural increase.** The maximum growth rate (in numbers of organisms) which a species can achieve under optimized natural conditions.

**Lake.** A naturally formed body of standing water which has moderate to large size and usually has a depth greater than 10 meters.

**Laminar.** A type of fluid flow characterized by smooth, sheet-like flow without internal turbulence.

**Limiting factor.** That required abiotic factor which, because of its relatively insufficient supply, limits the number of organisms which can be supported in an area.

**Logarithmic rate.** The data that form a straight line when plotted on a

logarithmic scale. Used especially in reference to growth rates.

**Macroflora.** Large (that is, visible to the unaided eye) plants.

**Marginal habitat.** A habitat which will support only a low density of a particular organism due to the habitat's less than optimal characteristics.

**Marine.** Pertaining to the sea or ocean; ocean-dwelling, and, accordingly, adapted to living in sea water.

**Metabolic activity.** The chemical exchanges and reactions carried out by living organisms. These include such activities as respiration, digestion, protein synthesis, waste product formation, etc.

**Mineral-water spring.** A source of water issuing from the ground that is rich in one or more minerals (for example, sulphur) and frequently has a high temperature. See Figs. 78, 79, pp. 168, 169.

**Molluscicide.** A substance which is applied to snail habitats for the purpose of killing and eliminating snails (such as niclosamide, endod extract, etc.). See pp. 94-99.

**Passive transport.** The movement of organisms from one locality to another by mechanisms other than the locomotor power of the organisms themselves.

**Perennial habitat.** Those habitats which continually support the presence of a species from one year to the next.

**Permanent body of water.** A body of water (lake, pond, stream, spring, marsh, etc.) that does not dry up periodically or occasionally.

**Pioneer species.** A plant or animal species which is adapted to colonizing newly created or newly altered areas as a first appearing species.

**Pond.** A body of standing water smaller and usually more shallow than a lake. See Figs. 94, 95, p. 179.

**Pool.** A small impounded body of water similar to a pond, but which has a higher replacement rate of water from its source.

**Population dynamics.** The interactions between birth rate, death rate,

fecundity and distribution of individuals within a population which determines population density in an area.

**Primary canal.** A main artificial waterway (Figs. 87, 88, p. 174) taking water from the primary water source to the general vicinity where water is to be used for irrigation. Smaller secondary, tertiary and quaternary canals then take the water to the actual plants to be watered (Figs. 89-91, pp. 175, 176).

**Quaternary canal.** A mud-lined canal taking water from a tertiary canal to the actual plants to be watered. See Fig. 91, p. 176.

**Rafting.** The passive transport of organisms over water by drifting flot-sam.

**Rehydration.** The intake of water by a water-depleted estivating organism.

**River.** A body of water of considerable volume flowing in a natural bed. As used here, a river is a body of flowing water more than 10 meters in width and 30 centimeters in depth. See Fig. 85, p. 173.

**Runoff.** The overland flow of storm-derived water.

**Secondary canal.** An artificial waterway which takes water from a larger primary canal to smaller tertiary canals, which then take water to the agricultural land to be irrigated. See Fig. 89, p. 175.

**Seep.** The emergence of water from the ground over a local area which does not have an obvious point-source of flow.

**Spring.** A source of water coming from the ground. See Fig. 77, p. 168.

**Spring pool.** A natural or man-made impoundment located in connection to the source of a spring. See Figs. 94, 95, p. 179.

**Stream.** A body of running water on land (for example, a river, brook, creek, etc.) flowing in a defined channel from a higher altitude to a lower altitude. As used here, a body of flowing water less than 10 meters in width, smaller than a river. See Figs. 82-84, pp. 171, 172.

**Substratum.** The physical bottom of a body of water.

**Swamp.** A marsh; land saturated with water and sometimes periodically covered with water; low, wet area supporting aquatic higher plants. See Figs. 98, 99, p. 181.

**Temporal.** Varying with time.

**Tertiary canal.** An artificial waterway which takes water from a larger secondary canal to smaller quaternary canals, which then take the water to the actual plants to be watered. See Figs. 90, 91, pp. 175, 176.

**Thermal spring.** A spring which discharges heated ground-water.

**Transmission site.** Physical localities at which a disease is transmitted.

**Turbulent.** A type of water-flow characterized by swirling, shooting, eddying or confused water direction within the water column. Non-laminar flow.

**Underground aquifer.** A large zone of free water located below the ground surface.

**Wadi.** The bed or valley of a stream. A sharply defined depression in a desert region.

**Water quality.** The condition and suitability for use of natural water in terms of dissolved substances, suspended materials, temperature and biological materials.

**Zoogeography.** The study of major distribution patterns of animals relative to the physical geography of regions.

**Zour.** The lowland beside a river which fills with water during the flooding season; the flood plain of a river.

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