Review

Biomphalaria alexandrina in Egypt: Past, present and future

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The African species of *Biomphalaria* appeared as a result of the relatively recent west-to-east trans-Atlantic dispersal of the *Biomphalaria glabrata*-like taxon. In Egypt, *Biomphalaria alexandrina* is the intermediate host for *Schistosoma mansoni*. *Biomphalaria alexandrina* originated in the area between Alexandria and Rosetta and has historically been confined to the Nile Delta. *Schistosoma mansoni* reached Egypt via infected slaves and baboons from the Land of Punt through migrations that occurred as early as the Vth Dynasty. The suggestion of the presence of *Schistosoma mansoni* infection in Lower Egypt during Pharaonic times is discussed despite the fact that that there is no evidence of such infection in Egyptian mummies. It is only recently that *Biomphalaria alexandrina* colonized the Egyptian Nile from the Delta to Lake Nasser. This change was likely due to the construction of huge water projects, the development of new water resources essential for land reclamation projects and the movement of refugees from the Suez Canal zone to the Delta and vice versa. The situation with respect to *Biomphalaria* in Egypt has become complicated in recent years by the detection of *Biomphalaria glabrata* and a hybrid between both species; however, follow-up studies have demonstrated the disappearance of such species within Egypt. The National Schistosoma Control Program has made great strides with respect to the eradication of schistosoma; however, there has unfortunately been a reemergence of *Schistosoma mansoni* resistant to praziquantel. There are numerous factors that may influence the prevalence of snails in Egypt, including the construction of water projects, the increase in reclaimed areas, global climate change and pollution. Thus, continued field studies in addition to the cooperation of several scientists are needed to obtain an accurate representation of the status of this species. In addition, the determination of the genome sequence for *Biomphalaria alexandrina* and the use of modern technology will allow for the study of the host–parasite relationship at a molecular level.

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1. History of *Biomphalaria alexandrina*

It has been hypothesized that *Biomphalaria* snails originated in South America after the continental divide, which occurred approximately 95–106 million years ago. The current presence of these snails in Africa is a consequence of the relatively recent west-to-east trans-Atlantic dispersal of the *Biomphalaria glabrata*-like taxon (Campbell *et al*. 2000). These snails may have been transported via the feathers of aquatic birds or on vegetation rafted across the ocean (Woodruff and Mulvey 1997). The successful colonization of this species is due to the fact that *Biomphalaria* is hermaphroditic and capable of self-fertilization. The recent origin of the African *Biomphalaria* species has been proven by the smaller genetic distances noted between them when compared to those noted among Neotropical species. *Biomphalaria alexandrina* lies within the African clade of a poorly differentiated Nilotic species complex (*B. alexandrina, B. choanomphala, B. smithi* and *B. sudanica*), species that primarily inhabit the Nile basin but which have also invaded many of the great lakes in the Nile drainage. It has been suggested that previous colonization may have taken place in a southward direction, with *B. alexandrina* giving rise to its close relative *B. sudanica* (DeJong *et al.* 2001).

In Egypt, the planorbid freshwater snail *B. alexandrina* is the intermediate host for *S. mansoni*. This snail has historically been confined to the Nile Delta. *B. alexandrina* is thought to have originated in the area between Alexandria and Rosetta (Malek 1958). In 1831, Ehrenberg identified the

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snails gathered from Lake Maryut close to Alexandria as *Planorbis alexandrina* (*B. alexandrina*) (Halawani *et al*. 1958). However, the detection of preserved shells of *B. alexandrina* in a Paleolithic site in the Egyptian Western Desert and in a Neolithic site in Sinai pointed to the fact that a larger geographic range occurred during more damp periods (Wendorf *et al*. 1976; Mienis 1992; Lotfy 2009). On the other hand, fossilized shells of freshwater snails, including *Bulinus truncatus*, but not *B. alexandrina*, have been recovered at late Paleolithic sites in the Upper Egyptian Nile valley (Edfu and Esna) (Gautier 1976). The intermediate host of *S. hematobium* was described by Audouin in 1826 as *Physa truncate* (*Bulinus truncatus*) in Savigny's *Description of Egypt*. This snail is present all along the Nile valley in Upper and Lower Egypt and is also noted to exist in the Baharia, Dakhla and Kharga oases (Watson 1958; Lotfy 2009).Thus, in the past, *B. alexandrina* was thought to be present only in Lower Egypt, while *Bulinus truncatus* was noted to be present in both Upper and Lower Egypt.

The ability of snail intermediate host shells to survive in favourable environments for thousands of years facilitates the study of schistosomiasis during historic and prehistoric times (Kloos and David 2002).

2. History of *Schistosoma* in Egypt

It has been suggested that the original home of schistosomes lies in the region of the African Great Lakes, and it is possible that the disease may have spread from there to the Middle East (Nelson *et al.* 1962). A reservoir of naturally appearing *Schistosoma mansoni* infection exists among the wild monkeys of East Africa (Wright *et al*. 1972), while *S. haematobium* is probably a somewhat late variant that has adapted much better to the human host than to other primate hosts (Wright *et al*. 1974).

Infected humans (slaves and dancing dwarfs, pygmies from Central Africa) and baboons were taken from the Land of Punt to Thebes through journeys that occurred as early as the Vth dynasty (c. 2494–2345 BC) until the reign of Ramses III (1182–1151 BC) of the XXth dynasty. One journey has been entirely reported and portrayed on the walls of the funerary temple of Queen Hatshepsut of the XVIIIth dynasty at Deir El-Bahri. Baboons and slaves were among the valuables she received. The goods were widely dispersed in Upper and Lower Egypt via the relatively fast flowing Nile. Hence, any imported schistosomal infection could have rapidly been spread all over the country. Because the distribution of *Schistosoma* generally follows the existence of its obligate snail intermediate host, *S. haematobium* became established in Upper and Lower Egypt and *S. mansoni* became established only in the Delta region of the Nile, the only environment suitable for its snail host (Adamson 1976).

Even though baboons were not indigenous to Egypt, they were commonly seen, and played a notable and mysterious role in religion. They were thought to be one of the vessels that could be the home for the Gods. They became an essential part of worship of the sun god Ra and the moon god Thoth. These sacred monkeys were kept in the temples and a cemetery for monkeys was discovered at Gabanet el Giroud at Thebes. They resemble the African species naturally infected with *Schistosoma* and their relatives probably came from central Africa to Egypt. The same sacred role of these animals was also prevalent in Lower Egypt as they were found in the temples of Thoth at Hermopolis Parva, a city in Lower Egypt. In addition to their role in religion, monkeys were also kept as pets in the houses of the upper class (Lortet and Gaillard 1905; Adamson 1976).

Schistosoma haematobium infection has been present in Ancient Egypt since the XXth dynasty (c. 1184–1087 BC). The clear existence of this species was proven after Ruffer's discovery of calcified *S. haematobium* eggs in the kidneys of mummies from that time (Ruffer 1910). However, older cases of schistosomiasis were later identified to have occurred in mummies 3000, 4000 and 5000 years ago by means of immunodiagnosis (ELISA) (Deelder *et al*. 1990). Since Ruffer's discovery, there has been much debate over whether the ancient Egyptians were aware of the parasite's existence.

Many Egyptologists considered the disease that was referred to as '*aaa*' in many papyri (the Ebers, the Berlin, the Hearst and the London Medical) to be hematuria. (Ghaliounghui 1987; Duke 2008). However, other recent evidence supports the interpretation of '*aaa*' as an evil 'influence' that was believed by the ancient Egyptians to have been brought about by either a god or a dead person (Halioua and Ziskind 2005). The descriptions of both '*aaa*' along with antimony-based remedies and honey in the Hearst Papyrus as a treatment for *hrrw*-worms (interpreted as the adult form of *S. haematobium*) are suggestive of urinary schistosomiasis. Remedies for hematuria have been reported in different papyri, such as 9 in the Hearst, 11 in the Berlin and 20 in the Ebers, suggesting that the illness was serious and widespread (Taha and Waked 2010).

To date, there is no clear documentation of the presence of *S. mansoni* in Ancient Egyptian material. Indeed, it is thought to have arrived in Egypt much more recently than *S. haematobium* (Kloos and David 2002). However, the above-mentioned information concerning the presence of *B. alexandrina* and the imported *S. mansoni* in Lower Egypt during Pharaonic times raises numerous questions. Was *S. mansoni* primarily the cause of a zoonotic disease during Pharaonic times? Were *Biomphalaria* snails not co-evolving with the imported parasite? Were infected human cases present but not diagnosed? Or was the infection diagnosed but not documented? This author suggests that both *S. haematobium* and *S. mansoni* infections were present during the same Pharaonic period. *Schistosoma haematobium* was present in Upper and Lower Egypt after the arrival of infected slaves, while *S. mansoni* was present in Lower Egypt after the downward dispersal of imported infected slaves and baboons. It is likely that infection with *S. mansoni* has not been identified due to the fact that the discovered mummies that were dissected were generally from Upper and not Lower Egypt, as Egyptian mummies from the former area were better preserved in large part due to the dry air in this region. In humid Lower Egypt, where *S. mansoni* was initially present, the majority of all mummies have perished. Added to that, there is lack of satisfactory mummified tissue from the lower social classes that were usually exposed to the parasite, as adequate mummification was performed mainly in the higher classes. During the later dynasties, mummification was offered to all classes of society; however, it was rare in the earlier periods during which schistosomiasis had established itself in Egypt (Adamson 1976). The high likelihood that both *S. haematobium* and *S. mansoni* infections were present during the same period of time is supported by the following facts: *S. mansoni*'s symptomatology is less dramatic than that for *S. haematobium*; thus, its presence would have understandably been overlooked or not mentioned by the ancients. Although no ova with lateral spines were detected in mummies, ova with no visible spines that may have been due to *S. mansoni* infection were detected (Taha and Waked 2010). In addition, some of the bowel treatments found in the medical papyri, especially in the Chester Beatty papyrus, which is focused on proctology, may refer to treating symptoms of *S. mansoni* (Jonckheere 1944).

Although the disease has been present since antiquity, it was not until 1851 that Theodore Bilharz found distome trematodes in urogenital blood vessels during postmortem examination of Egyptian corpses at Kasr El Aini hospital. He named the worm *Distomum haematobium* and considered the lateral spined eggs to be abnormalities (Bilharz 1852). In 1902, intestinal schistosomiasis was diagnosed by Sir Patrick Manson in the West Indies, where lateral-spined eggs alone were present. This new species was named *S. mansoni* after Sir Patrick Manson (Samboon 1907). In 1915, Leiper showed that the aquatic pulmonate snails of the genera *Bulinus* and *Biomphalaria* are the transmitters of *S. haematobium* and *S. mansoni*, respectively (Leiper 1915).

The change from being a hunting-gathering society to a more sedentary agricultural one, which occurred with the construction of canals, facilitated the transmission of *Schistosoma*. During Pharaonic times, the Egyptians utilized the Nile's annual flooding of basins as an irrigation system. This system was used to cultivate basic crops, such as wheat, barley and flax (Caminos 1997). Egyptian peasants cultivated vegetables and fruits using perennial irrigation via water-lifting devices, which are now known as *shaduf,* to transport water. During that time, the activities of maintaining daily life resulted in frequent contact with the Nile and canal water for domestic purposes (Hamdan 1961). During the reign of Mohamed Ali (1805–1848), who advocated the cultivation of long staple cotton, perennial irrigation was extended which resulted in the flourishing of the aquatic snails in the absence of the annual drying period (Kloos and David 2002).

3. The present situation of *B. alexandrina*

In the past few decades, with the increase in human demand for freshwater in Egypt, changes have occurred in the water habitats that influence snail distribution. These changes have resulted in alterations to the epidemiological distribution of schistosomiasis in Egypt, where *S. mansoni* has replaced *S. haematobium* in the Delta and has become well established in the northern part of Upper Egypt. Consequently, the prevalence of *S. mansoni* has continued to increase throughout Egypt with a subsequent decline in *S. haematobium*, which had nearly disappeared from the Nile delta. By 1979, *B. alexandrina* was recovered from canals in Aswan and Lake Nasser, indicating that the snail had colonized the Nile from the Delta to Lake Nasser (Mallett and Aboul-Ela 1979). In Africa, the presence of *B. alexandrina* has also been reported from Taourga (northwest Libya) and north Sudan between Khartoum and Kosti (Brown 1994).

This change in the epidemiology of this species in Egypt has been attributed to the following:

- Construction of barrages north of Cairo, the Low Dam at Aswan after 1900 and the High Dam at Aswan in 1964 led to a larger canal system and increase in perennial irrigation resulting in changes in Nile water velocity and a shorter winter closure period. There was also an increase in the pollution levels of the Nile waters and an increase in aquatic vegetation. *Biomphalaria alexandrina* snails are more tolerant of low oxygen as well as organic and chemical pollution levels; in addition, they prefer slower flowing water than *Bulinus truncatus* (Watts and El Katsha 1995). These changes have resulted in more stable snail habitats; thus, *Biomphalaria* snails, which were previously restricted to the Delta, are now being found in Upper Egypt (Kloos and David 2002).
- The refugees who moved from the Suez Canal zone to the Delta during the war became heavily infected with *S. mansoni*. When they returned home, the species was transmitted and became established due to the presence of *Biomphalaria* snails (Abdel-Wahab *et al*. 1979).
- Pollution is one of the many factors that may explain the alteration in the distribution of schistosomiasis along the course of the Nile, along with the sharp decrease in the prevalence of *S. haematobium* and the subsequent rise in the relative abundance of *S. mansoni*, as pollution is now widespread throughout the canals of the Delta (Loker 2005).

- The development of new water resources, which are essential for agricultural expansion, together with land reclamation projects have further exacerbated the problem (Mehanna *et al*. 1994).

The development of the Egyptian economy currently involves increasing agricultural production by reclaiming parts of the desert, a process taking place in all parts of Egypt. Nile water has been used to irrigate these newly reclaimed areas. A side-effect of many of these projects has been the introduction of schistosome parasites and their snail intermediate hosts, often to the Bedouin population, who have no previous exposure to the disease. In a study by El-Sayed *et al.* (1995), it was found that schistosomiasis spread to areas southeast of Ismailiya (El Manayef area) and east of Bitter Lake (El Morra area), North Sinai. Yousif *et al*. (1998a) found that *B. alexandrina* snails successfully established themselves in these areas in the desert, an area noted to have large temperature extremes. The authors posited that there could be a possible invasion of the snail vector into the El-Salam Project area in Northern Sinai, which is irrigated by a mixture of Nile and agricultural run-off, and a resulting emergence of schistosomiasis there. Toshka is another reclaimed project, which is located at the West Desert and is at a low altitude where the River Nile expands and branches to form a new irrigation system. Water velocity at this area is low and suitable for snail reproduction.

In these areas, there are many different social groups that have widely divergent priorities and minimal contact with each other, as well as inadequate infrastructure with respect to roads, transportation, water, sanitation and health services. As a result of these conditions, control strategies that are effective for the population living in the Nile Valley will have to be modified considerably if schistosomiasis is to be brought under control in reclaimed areas (Mehanna *et al*. 1994).

The situation of *Biomphalaria* in Egypt has become complicated in recent years by the detection of *B. glabrata* in Egyptian water canals. The snail had successfully established itself in *B. alexandrina* habitats in the Nile Delta region. A hybrid of these two species has been detected; *B. glabrata* and the hybrid were found to be susceptible to the Egyptian strain of *S. mansoni* and to cause a significant increase in *S. mansoni* transmission. The fact that *B. glabrata* transmits the Egyptian strain of *S. mansoni* effectively but is more tolerant than *B. alexandrina* to high temperatures, and has a greater reproductive potential and a longer life span, illustrates the significant impact that the introduction of such a species can have on regional transmission dynamics (Yousif *et al*. 1998b; Bakry 2009; Abou-El-Naga *et al*. 2011). Determination of the snail species using molecular techniques that amplify *ITS1* and *ITS2*, key reference genes, has been useful in confirming the presence of *B. alexandrina*, *B. glabrata* and their hybrid, which were found in Egyptian water channels after comprehensive morphological studies (Kristensen *et al*. 1999). By using the same molecular technique, a study was conducted in 2005 and showed that there was no evidence for the presence of *B. glabrata* or a hybrid of *B. alexandrina* and *B. glabrata* (Lotfy *et al*. 2005). Abou-El-Naga *et al*. (2011) conducted a study on *Biomphalaria* snails in Alexandria water channels. This study included the morphology of the external shell and the internal anatomy of the renal ridge together with molecular analysis using a species specific polymerase chain reaction (PCR) technique. The results confirmed the absence of *B. glabrata* and its hybrid in Alexandria water channels. The same results were obtained in five other governorates (Giza, Fayoum, Kafr El-Sheikh, Ismailia and Damietta) using the same molecular technique (Mohamed *et al*. 2011, 2012).

3.1 *Compatibility of* B. alexandrina

The degree of compatibility between local snails and schistosomes is an important phenomenon relevant to transmission. Results from field and lab studies (Haroun 1996; Abou-El-Naga *et al*. 2010) have shown that *B. alexandrina* snails lie within the lower categories of compatibility with *S. mansoni* when compared to other species studied by Frandsen (1979). *Biomphalaria alexandrina* snails from different governorates in Egypt were found to be equally susceptible to infection with a sympatric strain of *S. mansoni* (Cridland 1968).

3.2 *Reproduction and genetic studies of* B. alexandrina

Similar to that in many other species, outcrossing is the predominant mode of reproduction in *B. alexandrina* (Vrijenhoek and Graven 1992). However, these snails are readily selfed if isolated in the lab (Mulvey and Vrijenhoek 1984). In contrast, *B. pheifferi* from Kenya have shown a high degree of selfing (Bandoni *et al*. 1990). *Biomphalaria alexandrina* snails have a diploid chromosome number (2n=36) similar to many species in the genus *Biomphalaria*. The mitotic chromosomes of *B. alexandrina* are organized in three groups and consist of 8 metacentric pairs, 8 submetacentric pairs and 2 subtelocentric chromosome pairs (Bakry and El Garhy 2011).

The study of allozyme variation in *B. alexandrina* has shown that snails in Upper Egypt, Alexandria and Ismailiya exhibit some reduction in allelic diversity when compared to those in Qalyuobia near Cairo. In general, allelic diversity in snails decreases as a function of distance from Cairo. High rates of gene flow among populations inhabiting Qalyuobia tend to keep these snails genetically similar. Lower rates of gene exchange with the peripheral populations in Alexandria and Ismailiya would enhance the opportunity for the random loss of alleles in peripheral populations (Vrijenhoek and Graven 1992).

Genetics plays an important role in the resistance or susceptibility to *Schistosoma* in snail vectors. The compatibility characteristics of *S. mansoni* in *B. alexandrina* are inherited with resistance being a dominant trait (Abdel-hamid *et al*. 2006; Abou-El-Naga *et al*. 2010) in a manner similar to *B. glabrata* and *B. tenagophila* (Newton 1952; Rosa *et al*. 2005). By using RAPD-PCR, the resistant and susceptible marker bands in *B. alexandrina* have been determined (Abdel-hamid *et al*. 2006). The identification of these bands in field snails has considerable promise in investigating the genetic diversity of the snails in epidemiologic surveys. Such data would be an important component of studies exploring potential biological control measures.

3.3 *Snail control*

It is widely acknowledged that an integrated approach is required to bring about a long-lasting reduction in schistosomiasis transmission. Despite the great improvements in chemotherapy for infection using a single oral dose of praziquantel, there has been concern about the development of *S. mansoni* resistance to praziquantel in both laboratory and field conditions (Abdul-Ghani *et al*. 2009). Isolation of schistosome strains that are less susceptible to praziquantel in some Egyptian villages within the Nile Delta region indicates the need for additional antischistosomal drugs (Ismail *et al*. 1996). Recently, a new antischistosomal drug, mirazid (derived from myrrh; a resin from *Commiphora molmol* (Family Burseraceae)), was introduced to the Egyptian market; however, there are serious doubts about its therapeutic effect (Barakat *et al*. 2005). Given the demand for additional antischistosomal drugs and the absence of completely effective and safe vaccines, snail control is one of the cornerstones of schistosomiasis control programmes. This also highlights the importance of other interventions that aid in the reduction of disease transmission, such as improvements in sanitation, safer water supplies to the general population and health education (Hamed 2010). Therefore, increased understanding of snail host ecology is important for improving methods to eradicate the aquatic obligate intermediate host of this neglected yet persistent human disease.

A Geographic Information System (GIS) has been used to study the epidemiology and ecology of snail vectors in Egypt. Furthermore, it can help in predicting the impact of changes that influence snail habitats across large areas. Due to its dry atmosphere and clear sunny sky, Egypt is considered one of the best countries for the use of GIS (Yousif *et al*. 1999).

With respect to various snail control measures used, cement lining of ditches and application of chemical molluscicides have been quite effective in many countries. However, these strategies are often quite expensive when compared with the health budgets of developing countries (Hamed 2010). Plant molluscicides have been used for several years in Egypt and the best studied of these is the herb *Ambrosia maritima* (*Damsissa*) (El-Sawy *et al*. 1978). Attempts to control snails through the application of molluscicidal chemicals derived from either the chemical industry or from local indigenous plants is quite challenging given the increasingly strong public resistance to the widespread application of chemicals to the environment. Thus, these methods have been found to be neither economically feasible nor environmentally acceptable (Loker 2005).

One of the biological control strategies that has been used to control infection is the use of natural predators, such as fish (*Tilapia*), ducks and aquatic insects, which can act as natural enemies. Competitors of various non-target molluscs, such as *Physa acuta, Melanoides tuberculatus* and *Helisoma duryi*, may also be used. However, this method of control may carry unacceptable ecological risks (Cowie 2001). Thus, it is difficult to determine the level of snail control that is both financially and ecologically suitable as well as sufficient to break the cycle of *Schistosoma* (Loker 2005).

For genetic control of schistosomiasis, one strategy is based on the premise that snails resistant to parasitic infection could be used as biological competitors to replace existing susceptible snails in endemic areas (Coelho *et al*. 2004). This approach avoids the often destructive changes in the local ecosystem that accompany other forms of snail control. However, snail control strategies require a more thorough understanding of the genetics of the complex interrelationship between parasites and snails. The selection of actively resistant snails and the mass culture of them will likely increase the proportion of alleles that make snails resistant to current snail control methods. Preliminary studies have been applied to *B. alexandrina*; however, long term follow-up studies are needed for several snail generations (Abdel-hamid *et al*. 2006; Abou-El-Naga *et al*. 2010).

4. The future of *B. alexandrina* in Egypt

4.1 *Snail prevalence*

Many interacting factors may influence the future prevalence of *Biomphalaria* in Egypt. The construction of massive water projects, the increase in reclaimed areas, the impact of global climate change and the effect of pollution are among the factors that make it more difficult to predict where and when the snails will be present.

Watts and El Katsha (1995) have predicted a serious water shortage in Egypt in the near future. There has been an overgrowth of the population with increasing consumption of Nile water for agricultural, industrial and domestic needs. Egypt utilizes 5 billion cubic meters of water over its granted amount, according to the international agreements between the Nile countries, as there is limited utilization by the Sudan of its share. However, this amount will decrease as the Sudan continues to expand its own irrigated areas and industries (Radwan 1997).

Many water developmental projects will soon be constructed along the Nile River south of Egypt, and their impact on the distribution of snails along these water ways, especially Lake Nasser, must be studied. Thus, the identification and genotyping of the snails that are already present at the Lake, the study of their basic ecological factors, and the type and population density of the parasites is imperative.

Climate change, along with other forms of global environmental changes, alters pathogen transmission in freshwater habitats. The net effect of climate change on schistosomiasis dynamics in Egypt is dependent on the full spectrum of the direct and indirect effects of climate on host and parasite life histories. The effect of rising temperatures extends beyond simple changes in host or parasite geographical distributions to include significant shifts in the interactions between both, resulting in an increase or reduction in the severity of the disease (Paull and Johnson 2011).

Pollution has played a significant role in the reduction of some medically important snails and may continue to affect the epidemiology of schistosomiasis. There is an expectation that polluted snail water habitats in Egypt will be colonized by snails, such as physids, that have high levels of tolerance for pollution (Dillon *et al*. 2002; Loker 2005). These snails transmit dermatitis-causing avian schistosomes. Cercarial dermatitis has recently been regarded as an emerging infection (de Gentile *et al*. 1996). In general, cercarial dermatitis often goes unrecognized in endemic areas (Appleton 1984). Lotfy (2009) expected that after human schistosomes have been controlled in Egypt, cercarial dermatitis will likely become an issue of increasing public health concern for people in contact with freshwater.

With the great success of the National Schistosoma Control Program in Egypt and even if schistosomiasis is completely eradicated, it is imperative that a snail control strategy continue to be implemented given the role of the animal reservoir host in infection. The Nile rat, *Arvicanthis niloticus*, is a satisfactory host for *S. mansoni* in Egypt and is frequently found near or even in the water of irrigation systems in areas where schistosomiasis infection is common in both snails and man (Kuntz and Malakatis 1955; Lotfy 2009).

5. Dealing with the future

Little is known about the interaction between *B. alexandrina* and *S. mansoni* relative to that of *B. glabrata*. However, it should not be assumed that the fundamental interactions of *Schistosoma* with different snail species are the same; thus, the nature of this relationship should be specified for each species (Abou-El-Naga and Radwan 2012). In addition, further documentation of the genome sequence for *B. alexandrina* is needed. Such developments will advance the study of the basic biology of the snail and its interaction with the parasite at a molecular level using new technological approaches. RNA interference techniques (RNAi) may elucidate the function of genes that play a role in the defense against *S. mansoni* by facilitating functional studies of snail gene products (Jiang *et al*. 2006). Proteomic studies will provide information on the protein and peptide composition of individual snail organs or tissues (Roger *et al*. 2008). Microarrays may be helpful in identifying and studying the transcriptional activity of snail genes in response to parasite infection or any changes in the local ecology (Hanington *et al*. 2010).

Continuous field studies are needed to detect changes in the distribution and abundance of the snails that are due to global climate and ecological changes. Egypt is one of many developing countries where *Schistosoma* is prevalent. Thus, our knowledge concerning this species is dependent on the experience and knowledge of its malacologists, especially with respect to the conduct of surveys and the use of molecular approaches to confirm the results of various surveys. Finally, the cooperation of various malacologists and other scientists in related branches offers the greatest deal of hope for controlling *Biomphalaria* snails and breaking this ancient *Schistosoma* cycle.

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