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Key to the Identification of East and Central African Freshwater Snails of Medical and Veterinary Importance *

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This identification key has been prepared to enable field workers in eastern and centra Africa to identify the species and subspecies of snails acting as intermediate hosts of various flukes causing bilharziasis and related diseases in man and his domestic stock.

The area covered by the key is eastern Africa from the Sudan and Somalia in the north to Southern Rhodesia in the south. The key includes all species and subspecies of the three medically and veterinarily important genera, Lymnaea, Bulinus *and* Biomphalaria. *All other freshwater pulmonates of the area can be identified as to genus only.*

Those features of the shells and soft parts of snails which are used in identification are discussed in some detail, and indications are given as to methods of collection, preservation and dissection of snails.

INTRODUCTION

The taxonomy of snails is based upon both conchological and anatomical characters, and for their identification the same characters are used.[2] It is a widespread and common belief that shell characters have been abandoned as useless in modern malacology, but this is far from being the case. The higher groups are mainly based on anatomical characters, but in some groups the conchological characters are very important, and in the lower groups (such as species and subspecies) the shells are frequently just as important as or even more important than the soft parts for the taxonomy.

To a certain extent African freshwater snails may be identified on the basis of shell characters, but in some cases it is impossible to reach a safe result without an examination of the soft parts. Therefore the present identification key will make use of characters both from the shell and from the soft parts. Descriptions of the shell and the soft parts are given below, together with explanations of the technical terms.

SHELLS

All African freshwater snails possess a shell; this is usually spirally coiled, but some small forms have a cap- or shield-shaped shell. Several have a lid or operculum attached to the dorsal side of the " tail ", by the aid of which the opening of the shell can be closed when the snail has retired into it. Snails with such an operculum (Fig. 1) belong to the class Prosobranchia, while snails without an operculum usually belong to another class, the Pulmonata. Only freshwater pulmonates of eastern and central Africa can be identified by the aid of the present key.

The shells of freshwater pulmonates offer a great number of characters useful in taxonomy and for identification: the general shape; the number, coiling and shape of the whorls; the shape and

* Eastern Africa has not yet been thoroughly investigated as regards freshwater snails and the occurrence of hitherto unknown forms cannot be excluded. It is hoped that this identification key will stimulate interest in these important snails and result in an increased number of snails being sent to the WHO Snail Identification, Danmarks Akvarium. For further information on *Bulinus* and *Biomphalaria* the reader is referred to: Mandahl-Barth, G. (1958) *Intermediate hosts of* Schistosoma: *African* Biomphalaria *and* Bulinus, Geneva (*World Health Organization: Monograph Series*, No. 37); and Mandahl-Barth, G. (1960) *Bull. Wld Hlth Org.*, **22**, 565.

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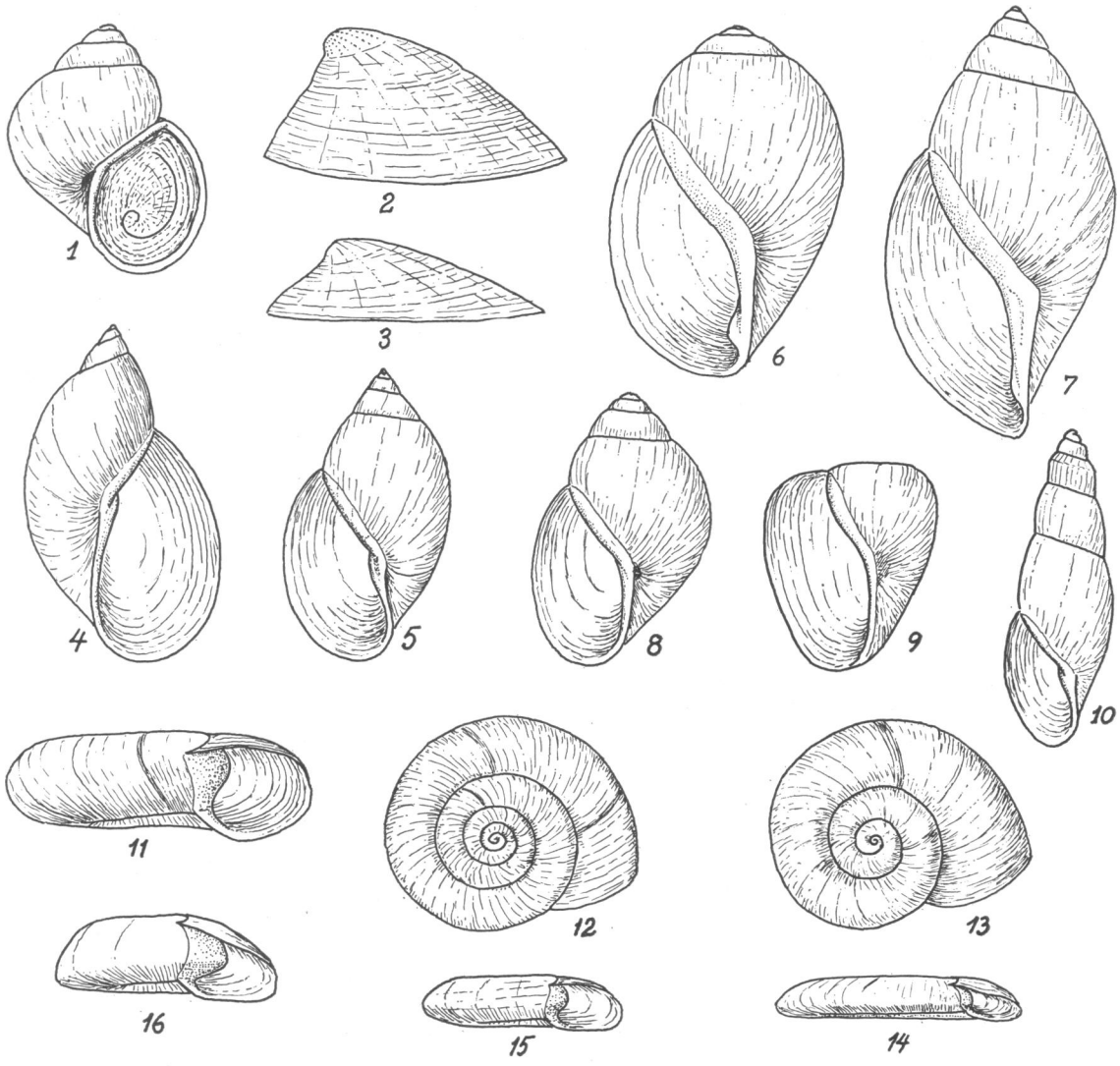
[2] Zoological taxonomy, or systematics, is the science of classification of animals, based on descriptions of all species, and is thus a synthetic procedure. Identification is an analytical procedure using the systematic characters for identifying the individual species.

FIG. 1-16
SHELLS OF FRESHWATER SNAILS



1. Prosobranch (*Gabbia*) with operculum. 5 mm high.
2. *Burnupia* sp. 5 mm long.
3. *Ferrissia* sp. 3 mm long.
4. *Lymnaea natalensis*. 15 mm high.
5. *Physa borbonica*. 12 mm high.
6. *Bulinus (Physopsis) globosus*. 16 mm high.
7. *Bulinus (Ph.) nasutus*. 18 mm high.
8. *Bulinus (Bulinus) tropicus*. 12 mm high.
9. *Bulinus (B.) truncatus trigonus*. 9 mm high.
10. *Bulinus (B.) forskalii*. 14 mm high.
11. *Biomphalaria pfeifferi*. 14 mm wide.
12. *Biomphalaria sudanica*. 15 mm wide.
13. *Biomphalaria pfeifferi*. 15 mm wide.
14. *Anisus* sp. 5 mm wide.
15. *Gyraulus* sp. 4.5 mm wide.
16. *Lentorbis* sp. 5 mm wide.

development of the opening, also called the aperture; the sculpture, etc.

As regards the general shape of the shell, we find among African freshwater pulmonates three different types:

1. The cap- or shield-shaped shell (Fig. 2 and 3) with only faint traces of coiling. All snails with shells of this type are small and belong to the family Ancylidae.

2. The ovate shell, higher than it is wide, consisting of three or more whorls, and usually with a large aperture (Fig. 4-9). In some species the shell is drawn out in length and is then termed turreted (Fig. 10). *Lymnaea*, *Bulinus*, and *Physa* have shells of this type.

3. The disc-shaped shell with all the whorls placed in almost the same plane. This is the usual type of shell of planorbid snails (Fig. 11-15). Some planorbids have the upper side of the shell evenly rounded and the under side more or less flat, and such shells are called lens-shaped (Fig. 16).

The direction of the coiling is also an important character. A coiled shell may be either dextral or sinistral. In the dextral or right-handed shell the coiling runs clockwise when seen from the top of the shell (Fig. 4), while in the sinistral or left-handed shell the coiling runs the opposite way (Fig. 5-10). When a shell is placed with the top upwards and the aperture facing the observer, the aperture is to the right when the shell is dextral, and to the left when the shell is sinistral.

Whorls (Fig. 17 and 18)

In most snails the whorls are rounded, but some species have more or less angular whorls. If the angle is sharp and reminiscent of a keel, the whorls (and the shell) are termed carinate.

The number of whorls of the full-grown shell may be distinctive. If two shells of the same size have different numbers of whorls, their growth must have been different. The shell with the greater number has whorls slowly increasing in width, while a shell of the same size, but with fewer whorls, has more rapidly increasing whorls. The best way to count the number of whorls is shown in Fig. 18. The stippled arrows show the direction of counting, and the broken line the limits of each whorl. Thus 1, 2, and 3 indicate the end of the first, second and third whorl respectively.

The last (or lowest) whorl is termed the ultimate whorl, or more frequently the body-whorl, because it is the largest and therefore contains the greater part of the body. All whorls above the body-whorl together form the spire, the tip of which is called the apex. The relation between the height of the spire and the height of the body-whorl (measured as the height of the aperture) is sometimes an important and easily observable character.

The suture is the line formed by the junction of the whorls. When these are convex the suture is usually deep, while flat whorls as a rule form a shallow suture.

In closely coiled shells the axis, formed by the inner walls of the whorls, is massive, but most shells are not so closely coiled, and the axis forms a narrower or wider conical tube. The axis is usually termed the columella. The opening of the columellar tube on the under side or basis of the shell is called the umbilicus. Shells with a wide umbilicus are umbilicate. When the umbilicus is narrower, the shell is perforate; and when no umbilicus is present, the shell is imperforate. In many species the umbilicus is partially or completely closed by the expanded and reflexed columellar margin of the aperture.

FIG. 17
MORPHOLOGY OF A SNAIL SHELL (*BULINUS FORSKALII*)

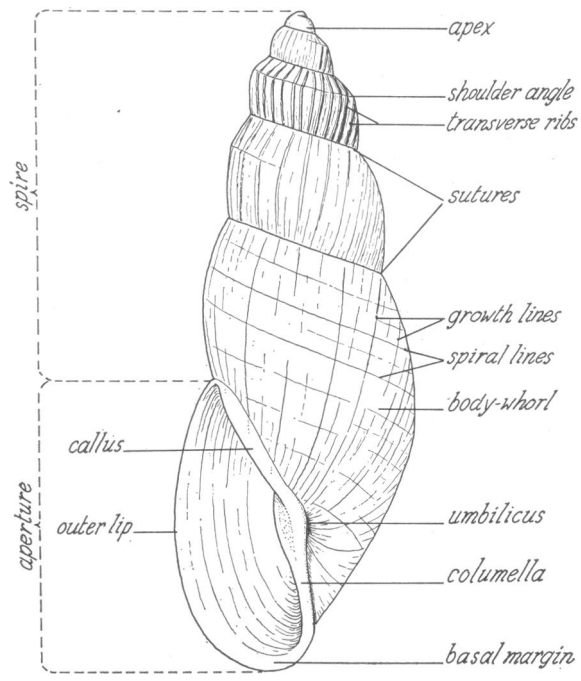
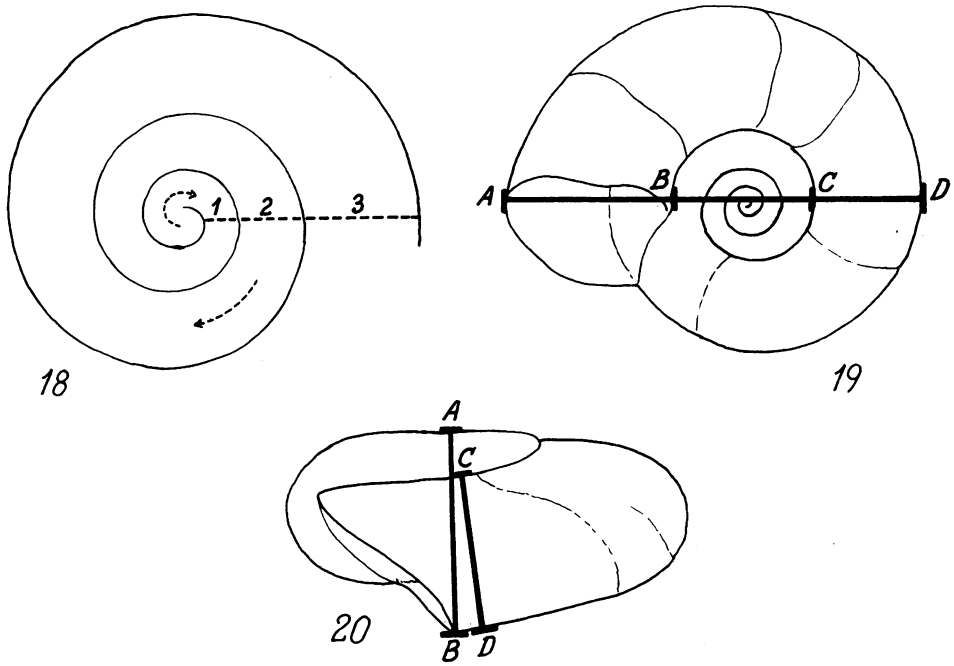


FIG. 18-20
SHELL DIMENSIONS



18. Counting of whorls. The stippled arrows show the direction of counting, and the stippled lines the limits of the first, second and third whorl.
19. Diameter of shell (A-D) and diameter of umbilicus (B-C).
20. Height of shell (A-B) and height of last whorl (C-D).

The aperture is the opening of the shell through which the lower part of the body is protruded. The aperture is continuous when its margin is formed entirely by the body-whorl, but most freshwater pulmonates have the margin interrupted, which means that the upper part is formed by the penultimate whorl, and only the outer margin (or outer lip), the basal margin and the columellar margin (or columella) are formed by the body-whorl. Frequently the outer lip is connected with the columella by a thin layer of lime (the callus) on the wall of the penultimate whorl. A truncate columella means that the columella does not pass evenly into the basal margin.

Shell sculpture (Fig. 17)

The sculpture of the shell is also important. In most freshwater pulmonates the sculpture is so delicate that it is only visible under a powerful lens or a microscope, and is then termed microsculpture. Sculpture running parallel to the whorls is spiral; when it is placed at a right angle to the direction of the whorls it is transverse. In several shells the only sculpture present is growth lines: more or less regular transverse ridges or lines formed by the growth of the shell and each representing former outer lips. If the transverse lines are so strong that they stand out like small ribs, the shell is costulate. In some shells the costulation is restricted to some of the upper whorls, in others it covers all the whorls. A more irregular sculpture reminiscent of small waves is termed corrugation. A spiral sculpture is usually present as delicate spiral lines. When such lines cross the growth lines, the shell becomes reticulate. The spiral sculpture may also consist of spirally arranged small dots or short transverse striae arranged in spiral bands. The first whorl and a part of the second (i.e., the embryonic whorls formed in the egg) usually differ in microsculpture from the rest of the shell.

Shell colour

The colour of the shell is, in most cases, of little importance in freshwater pulmonates. It is a lighter or darker horny colour, ranging from almost pure white to a rather dark brown. Some species normally have a glossy shell, others a duller; but very frequently both the colour and the microsculpture are concealed by a reddish or dark coating which must be removed before the details can be examined. The best way to clean the shells is to place them for a few minutes in a saturated aqueous solution of oxalic acid, which will dissolve the coating but not attack the shells. After cleaning, the shells should be washed in tap-water, preferably of a rather high calcium content.

Measurements of shells (Fig. 19 and 20)

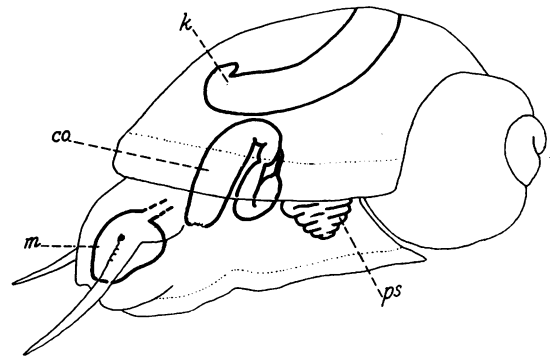
The height of a shell is the greatest distance between the basal margin and the uppermost point of the shell, usually the apex, taken parallel to the axis (Fig. 20, line A-B). The width or diameter is the greatest distance between the outer lip and the opposite side of the shell measured at a right angle to the axis (Fig. 19, line A-D). The height of the spire and of the aperture should also be measured parallel to the axis. The width of the aperture is the greatest distance between the outer lip and the columellar margin (Fig. 19, line A-B). The height of the last whorl is measured just behind the aperture and at a right angle to the longitudinal direction (Fig. 20, line C-D). In some planorbids the diameter of the umbilicus is an important taxonomic character and is taken as the greatest diameter between the sutures on the under side of the shell (Fig. 19, line B-C). A sliding caliper is very useful for measuring shells.

SOFT PARTS

The soft parts of snails offer several characters useful in taxonomy and for identification. Of the external features mention must be made of the broad triangular tentacles of *Lymnaea* in contrast to the slender, tapering, cylindrical tentacles of the Planorbidae and Physidae. The Planorbidae possess a false gill or pseudobranch which is not present in *Physa* and *Lymnaea*. The pseudobranch is a folded lobe on the left side of the mantle border near the opening into the lung (Fig. 21).

Of the internal organs the radula, the copulatory organ and, in a few cases, the pallial organs are important.

FIG. 21
LOCATION OF IMPORTANT ORGANS



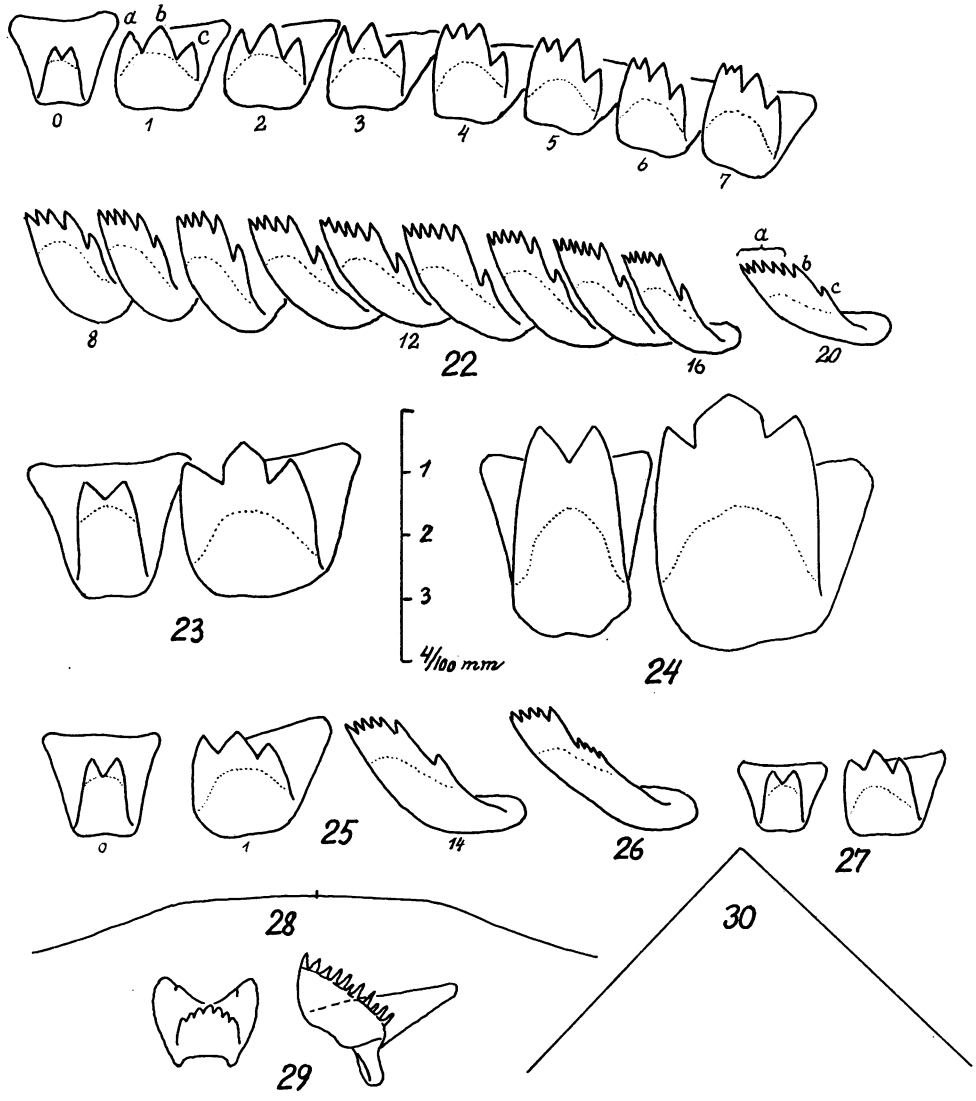
co = copulatory organ. *k* = kidney.
m = buccal mass (containing the radula).
ps = pseudobranch.

The radula is situated in the buccal mass (Fig. 21) as a membranous plate on the upper side of which a great number of small teeth are placed in transverse and longitudinal rows. Each transverse row has in the middle a central tooth and, symmetrically arranged on both sides of this, a number of lateral and marginal teeth (Fig. 22). The central tooth is usually somewhat smaller than the adjoining lateral teeth and has only one or two cusps. The lateral teeth have three main cusps: the endocone, the mesocone, and the ectocone (Fig. 22, *a*, *b*, *c*). In most forms the mesocone is simply triangular (the base of the cusp forms the third side of the triangle), but some have pentagonal or arrowhead-shaped mesocones (Fig. 23 and 24). Laterally the endocones become divided into two or more cusps, while the mesocones and the ectocones are rarely divided. The marginal teeth are long and obliquely placed, and their endocones and sometimes also the ectocones are divided into a number of minute cusps (Fig. 26). The family Physidae has more than three cusps on all the teeth (Fig. 29).

The copulatory organ (Fig. 31) is in some cases a good distinguishing character, but it should not be forgotten that both age and sexual stage of the snails and the preservation method have a great influence on the size and proportions of the organ. In all freshwater pulmonates the copulatory organ is divisible into two parts: an upper part consisting of the vergic sheath and the verge and a lower —usually more bulky—part, the preputium, a muscular tube connecting the vergic sheath with the surface of the body. The male opening is just behind

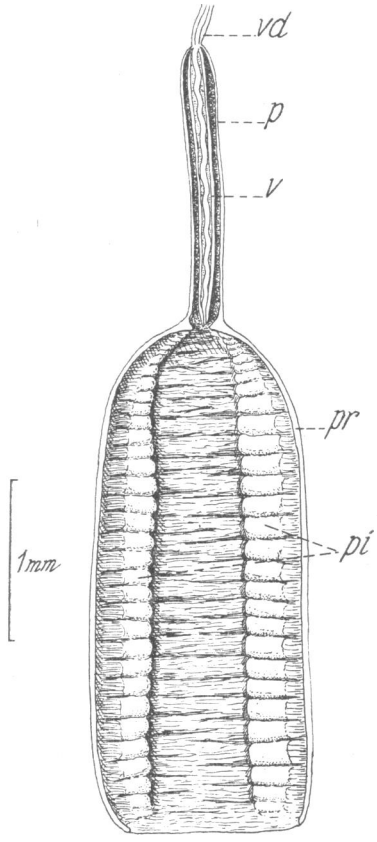
FIG. 22-30

RADULA TEETH



22. *Bulinus coulboisi*; half a transverse row. 0 = central tooth; 1-7 = lateral teeth; 8-20 = marginal teeth; *a* = endocone; *b* = mesocone; *c* = ectocone.
23. *Bulinus truncatus.* Central tooth and first lateral tooth.
24. *Bulinus mutandaensis.* Central tooth and first lateral tooth.
25. *Biomphalaria pfeifferi pfeifferi.* Central tooth, first lateral tooth and a marginal tooth.
26. *Biomphalaria pfeifferi rüppellii.* Marginal tooth.
27. *Biomphalaria sudanica.* Central tooth and first lateral tooth.
28. Planorbidae. Shape of a transverse row.
29. *Physa.* Central tooth and a lateral tooth.
30. *Physa.* Shape of a transverse row.

FIG. 31
LONGITUDINAL SECTION OF COPULATORY ORGAN OF *BIOMPHALARIA PFEIFFERI*



p = vergic sheath. *pr* = preputium.
pi = pilasters. *v* = verge.
vd = vas deferens.

the left tentacle in sinistral snails and behind the right tentacle in dextral snails.

For the taxonomy of the Planorbidae the copulatory organ is very important. In contrast to all other Planorbidae *Bulinus* and related forms have a verge completely introverted when not in use. *Biomphalaria* and all other planorbid snails, like most other pulmonates, have an everted verge. Certain species of *Bulinus* frequently have no copulatory organ and are then termed aphallic. The ratios vergic sheath to preputium and verge to vergic sheath may also be of systematic value. The ratios are based upon the length of the organs. These characters, however, are a little difficult to use, because they are dependent on the sexual stage of the snail and also on the method of preservation.

The pallial organs are the organs situated on the mantle and may also be of systematic significance. Besides presence or absence of a pseudobranch, already mentioned above under external features, the kidney also offers distinguishing characters in certain forms. The subgenus *Physopsis* of the genus *Bulinus* has a ridge, or fold, on the ventral side of the kidney, while the subgenus *Bulinus sensu stricto* does not possess such a ridge (Fig. 32).

COLLECTION, PRESERVATION AND DISSECTION OF SNAILS

Occurrence

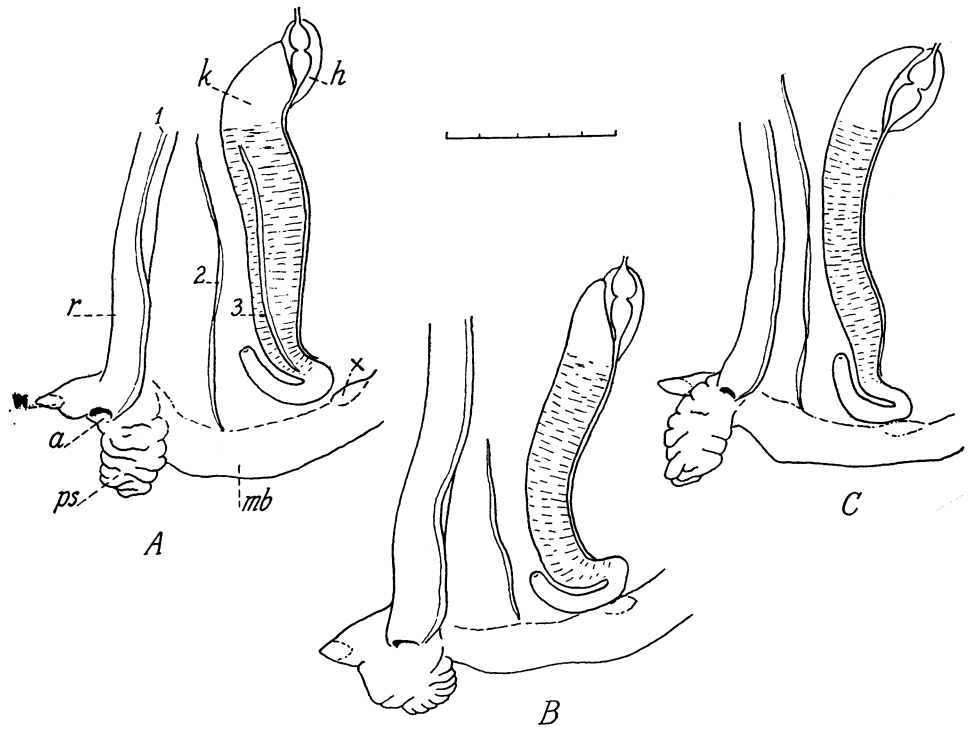
Freshwater pulmonates prefer stagnant or slowly running water. On the exposed shores of big lakes and in fast-flowing rivers there are few if any pulmonates. They are also usually lacking in very acid or alkaline water; but apart from these exceptions they can be found in all types of freshwater bodies from the greatest lakes to small rainwater pools. In the great lakes they are most plentiful in sheltered bays with shallow water, but sometimes they live at greater depths, down to 10 metres or more. It is, however, the smaller lakes, ponds and sluggish streams that are the preferred habitat for most of the species. Water-lilies are as a rule indicative of good conditions for snail life, while Nile-lettuce seems to indicate poor conditions. Certain species of freshwater pulmonates live preferably or entirely in temporary pools, even in pools that hold water during a few months of the year only. Many populations of freshwater pulmonates are subjected to great fluctuations, which means that a species abundant at one visit might seem to be very scarce a few months later. Repeated visits are necessary to be sure that all species have been found, even in small ponds.

Collection

In Africa it is usually not advisable to collect freshwater snails by picking them up by hand. The risk of becoming infected with *Schistosoma* is too great. Of course, rubber or plastic gloves protect perfectly against such infection, but they are most unpleasant to wear in a hot climate. The use of a suitable long-handled net is preferable, especially where there is a rich submerged vegetation. The net should be shaken in the water after it has filled with plants. Most snails will then loosen their hold on the plants and drop to the bottom of the

FIG. 32

PALLIAL ORGANS OF THREE SPECIES OF *BULINUS*



A = *Bulinus (Physopsis) globosus.* B = *Bulinus (Bulinus) tropicus.* C = *Bulinus (Bulinus) forskalii.*
The scale is in millimetres for A and B, and in half-millimetres for C.

a = anus.
h = pericardium with heart.
k = kidney.
mb = mantle border.
ps = pseudobranch.
r = rectum.
x marks the places where the anal part has been separated from the mantle border.

1 = rectal fold. 2 = fold between rectum and kidney. 3 = renal fold.

net. The net may also be emptied into a suitable white enamel or plastic dish, where it is easy to see the snails and pick them up with a pair of forceps.

For collecting in deeper water a dredge is indispensable. It consists of a triangular frame of flat iron to which is attached a bag of nylon net. The frame should have a side length of, for instance, 40 cm. To a ring in each of the three corners a small piece of rope is fixed. The free ends of these ropes are collected in another ring to which a long rope is tied. The length of this rope depends on the depth of the water; it should be about three times the depth. The dredge can be used either from a boat or from the shore (or a bridge). It should be pulled at such a speed that it just scrapes the top layer of the bottom. If pulled too fast it will go above the bottom, and if too slowly it will dig itself into the bottom. With some experience it is easy to judge by the feel of the rope whether the dredge is working properly. As in the case of the hand-net, the dredge should be emptied into a dish for sorting out the snails.

If the snails are wanted alive in the laboratory, it should be remembered that they survive better when transported in a bottle with very little water than they do in a bottle with much water. Small or fragile specimens should never be transported in the same bottle as large, heavy specimens.

Preservation

The easiest way of preserving snails is to put them into 70% ethyl alcohol. For identification this method is sufficient, if the volume of alcohol is at least twice the volume of snails. If the snails are wanted for anatomical purposes, it is better to have them preserved extended. For this the following procedure is recommendable.

The snails are placed in a small jar containing sufficient water to allow them to creep freely around. Then a few drops of a saturated solution of menthol in alcohol are added to the surface; the menthol will narcotize the snails with the lower portion of the body extended. When the snails no longer react to being touched they are transferred to 70% alcohol, which kills them quickly. After 24 hours the snails may be dissected, but if they are to be kept for any length of time, the alcohol should be changed, because the first portion is diluted with water from the snails.

Dissection

The dissection itself depends, of course, on which organs are wanted for a closer examination, but usually the best way is to remove the mantle by cutting it free between the rectum and the body and then along the mantle border. After these two cuts the mantle is easily pulled off. Both the radula and the copulatory organ are situated in the forepart of the extended snail, so a third cut along the dorsal median line from the mantle border to the snout will make them accessible. When the copulatory organ is dissected out, it should be stained with borax-carmine, eosine, chrysoidin or another suitable stain and transferred to 96% alcohol for removal of most of the water and the surplus stain. Then it is placed on a slide in a drop of Euparal and covered with an ordinary cover-slip, if necessary with a small piece of Plasticine under each corner in order to avoid too much flattening of the organ.

Preparation of radula

The buccal mass containing the radula is dissected out and put into a 5% solution of potassium hydroxide. If the snail is fresh or preserved in alcohol, the soft parts will be dissolved in about 24 hours, while formol-preserved material will take longer. The process can be accelerated by cautious heating. When the soft parts are dissolved, the radula is transferred to a 10%-15% solution of acetic acid, where it is carefully cleaned. After cleaning, it is placed into a saturated solution of chrysoidin in water, where it is left for about five minutes. It is then transferred to 96% alcohol, in which the surplus water and stain are removed, and embedded in Euparal on a slide. It is important that the radula be placed with the teeth upwards and carefully stretched out before the cover-glass is put on. For its examination a microscope with a magnifying power of at least 500× is necessary.

Storage of shells and preserved specimens

Since all preservation fluids after some months or years will attack the shells, it is wise to keep some shells dry and other specimens of the same lot preserved in alcohol. With snails killed and kept in alcohol for at least a couple of days or killed in boiling water it is usually possible to extract the body with the aid of a pin with the point bent in the form of a small hook. A large insect-pin is excellent for the purpose, and when fixed in a wooden handle and bent in a curve corresponding to the body-whorl of the snail, it forms a useful implement. It is seldom possible to extract the bodies of small snails, and in such cases the snails are placed in 96% alcohol for 24 hours, after which the soft parts are allowed to dry inside the shells. When the shells are completely dry they are put in suitable tubes and labelled. The tubes should be plugged with cotton-wool and kept in darkness.

The best way to keep preserved specimens is to put them into a tube filled with 70% alcohol, plugged with cotton-wool and stored with other tubes in a bigger jar, also filled with 70% alcohol and tightly closed in order to prevent evaporation of the alcohol. Each tube should, of course, be properly labelled, with indication of the exact locality, the date, the name of collector, and, if possible, the name of the species for each lot. As most African localities are difficult to locate on a map, it is advisable that the nearest big village or town be indicated. Labels should be of good paper and written with Indian ink.

Dispatch of specimens

Dry shells and preserved specimens may be sent in any suitable container. Each lot should be properly labelled. Too frequently specimens have been sent with illegible labels written in pencil on poor paper or with a reference number of no value to the recipient. Of course, reference numbers may be used, if the sender remembers to send the clue. For air mail, light plastic containers are advantageous

when placed in a sufficiently strong box or tin. Heavy specimens should never be sent in the same container as small and fragile specimens.

Live specimens may be sent packed firmly between layers of damp, but not wet, cotton-wool in a suitable tin. The specimens should always be arranged in a single layer and should not touch one another. Several layers of snails and cotton-wool may be arranged in the same tin. Packed in this way live snails can usually endure 5-6 days' travel or more. Live specimens should also be labelled properly, but the labels should be placed outside the tin.

KEY TO THE GENERA OF EAST AND CENTRAL AFRICAN FRESHWATER PULMONATES AND TO THE SPECIES AND SUBSPECIES OF *LYMNAEA*, *BULINUS* AND *BIOMPHALARIA*

1.	Normally shell has lid (operculum) (Fig. 1); in most cases radula has 7 teeth in each transverse row; true gill present in pallial cavity; unisexual . . . . . (Several species of prosobranchs are known from eastern Africa. Widely distributed and commonly met are the genera *Bellamya*, *Pila*, *Lanistes*, *Gabbia*, *Cleopatra* and *Melanoides*. None of these is known to be of medical importance.)	Prosobranchia
	Operculum and true gill absent; radula with more than 7 teeth in each transverse row; hermaphrodite (Pulmonata)	2
2.	Shell spirally coiled, consisting of 3-7 whorls (Fig. 4-14)	4
	Shell cap- or shield-shaped (Ancylidae) (Fig. 2 & 3) . . . . . (This family comprises in eastern Africa an uncertain number of small or very small species, rarely exceeding 5 mm in length.)	3
3.	Top of shell (apex) radially punctate; shell usually rather high, cap-shaped (Fig. 2)	*Burnupia*
	Apex radially striate; shell flatter, shield-shaped (Fig. 3)	*Ferrissia*
4.	Shell ovate or turreted, distinctly higher than wide (Fig. 4-10)	5
	Shell disc- or lens-shaped, much wider than high (Fig. 11-14)	29
5.	Shell dextrally coiled (Fig. 4); tentacles broad, triangular *(Lymnaea)*	6
	Shell sinistral (Fig. 5-10); tentacles tapering filiform	8
6.	Rather small; shell 7-12 mm high and consisting of 5-6 slowly increasing whorls; spire about as high as aperture . . . . . (*Lymnaea truncatula* (Müller) was possibly introduced into eastern and southern Africa, but is now widely distributed, although local in occurrence. Intermediate host of *Fasciola hepatica* in cattle and small stock.)	*Lymnaea truncatula* (Müller)
	Shell up to 25 mm high and consisting of 4-5 more rapidly increasing whorls; spire not exceeding half the height of aperture	7
7.	Sculpture consists of growth lines only . . . . . (*Lymnaea natalensis* (Krauss) is the common African *Lymnaea*, very variable in size and shape. Intermediate host of *Fasciola gigantica* in cattle and other herbivorous mammals.)	*Lymnaea natalensis* (Krauss)
	Sculpture consists of growth lines crossed by fine spiral striae forming a distinct reticulation . . . . . (*Lymnaea columella* Say is an American species introduced into South Africa and spreading northwards; now also found in Southern Rhodesia.)	*Lymnaea columella* Say

8.	Shell has a pointed apex, shallow sutures and a twisted columella (Fig. 5); pseudobranch not present; radula teeth arranged in broadly V-shaped transverse rows (Fig. 29 & 30); the animal moves fast for a snail . . . . . (The shell of *Physa* is easily confused with *Bulinus*, but the radula and the absence of a pseudobranch are distinctive. Probably of no medical or veterinary importance.)	*Physa*
	Apex usually blunt or obtuse; sutures are deeper and columella straight in most species (Fig. 6-10); pseudobranch (Fig. 21, *ps*) always present; radula teeth arranged in slightly curved transverse rows (Fig. 28) (genus *Bulinus*)	9
9.	Columella more or less truncate below (Fig. 6 & 7); microsculpture, if present, consists of a few spiral lines, spirally arranged short transverse lines or dots, rarely of wrinkles intersected by fine spiral lines, or an irregular corrugation; ridge on ventral side of kidney is usually present (Fig. 32 A) (subgenus *Physopsis*)	10
	Columella not truncate (Fig. 8-10); microsculpture, if present, consists of transverse ribs; no spiral sculpture; kidney has no ridge on ventral side (Fig. 32 B & C) (subgenus *Bulinus sensu stricto*)	16
10.	Microsculpture on spire consists of a corrugation; more rarely a spiral sculpture is present; shell is almost white (when clean) and with shouldered whorls . . . (*Bulinus (Ph.) abyssinicus* (Martens) is only known from Somalia, where it acts as intermediate host of *Schistosoma capense*.)	*Bulinus (Ph.) abyssinicus* (Martens)
	Microsculpture of spire is spiral or no particular sculpture is present; colour of shell is a lighter or darker horny brown	11
11.	Vergic sheath distinctly longer and wider than preputium. (Immature specimens have vergic sheath equal in length to preputium and cannot be identified with certainty)	12
	Vergic sheath not longer and not much wider than preputium	13
12.	Shell usually 12-15 mm high . . . . . (The typical *africanus* is found in South Africa, Mozambique and the Federation of Rhodesia and Nyasaland, where it acts as intermediate host of *Schistosoma capense*.)	*Bulinus (Ph.) africanus africanus* (Krauss)
	Shell usually 14-17 mm high . . . . . (The form *ovoideus* is closely related to the nominate form and hardly deserves subspecific status. Known from British East Africa and occurs possibly in the Sudan and Ethiopia. Intermediate host in Kenya, but not in Uganda.)	*Bulinus (Ph.) africanus ovoideus* (Bgt.)
13.	Full-grown shell consisting of 5-6 whorls; spire broadly conical with a rather pointed apex (Fig. 7); microsculpture often diffused all over the shell	14
	Full-grown shell consisting of 4-4.5 whorls; spire usually short with a blunt apex (Fig. 6); microsculpture restricted to the upper part of shell or absent . .	15
14.	Spire is rather low, about half as high as aperture . . . . . (The typical *nasutus* is found in the coastal areas of Kenya and Tanganyika, where it acts as intermediate host of *Schistosoma capense*. Sometimes difficult to separate from high-spired forms of *B. globosus*, but greater number of whorls and usually more diffused microsculpture are distinctive.)	*Bulinus (Ph.) nasutus nasutus* (Martens)
	Spire is higher, almost equal in height to aperture . . . . . (The subspecies *productus* replaces the nominate form in inland areas. Known from Uganda, western Kenya and north-western Tanganyika. Intermediate host of *Schistosoma capense*.)	*Bulinus (Ph.) nasutus productus* M.-B.

15. More or less pronounced spiral sculpture; full-grown shells 15-20 mm high; columella as a rule with a distinct truncation. Clean and fresh shells usually glossy and of a light brownish colour . . . . . *Bulinus (Ph.) globosus* (Morelet)

(*B. (Ph.) globosus* is widely distributed in Africa south of the Sahara and rather variable in size and shape. Sometimes the copulatory organ has a relatively longer vergic sheath and in such cases is difficult to separate from not fully mature *B. africanus*. When the two species occur together the shells are usually distinctly different, but the differences are not the same in all mixed populations and therefore difficult to describe. The common intermediate host of *Schistosoma capense*.)

No special microsculpture; full-grown shells 10-15 mm high; truncation of columella is almost obsolete; colour of shell is a rather dull brownish or yellowish . . . . . *Bulinus (Ph.) ugandae* (M.-B.)

(*B. (Ph.) ugandae* is known from Lake Victoria, Uganda and the Sudan. Around Lake Victoria the snail is dark, almost black, with a rather dark-brownish shell. In northern Uganda and the Sudan it is much lighter and the shell is yellowish. Does not act as intermediate host of *Schistosoma*.)

16. Spire not longer (in most cases shorter) than aperture; height of shell less than twice the diameter (Fig. 8 & 9); no shoulder angle on upper whorls 17

Spire typically longer than aperture; if not, a distinct shoulder angle is present on upper whorls. Height of shell is greater than twice the aperture (Fig. 10 & 17) 28

17. Mesocone of lateral teeth is simply triangular and deeply separated from endocone and ectocone (Fig. 22); copulatory organ usually present (except *B. coulboisi*; see 19) 18

Mesocone of lateral teeth is arrowhead-shaped and more coalescent with ectocone and endocone (Fig. 23 & 24); copulatory organ frequently lacking . . 23

18. Full-grown shell, consisting of 4-4.5 whorls, is only 4-5 mm high; umbilicus not completely closed by the broadly expanded and reflexed columellar margin; convex whorls and deep sutures give spire a step-like appearance . . . . . *Bulinus (B.) reticulatus* M.-B.

(*B. (B.) reticulatus*, the smallest species of *Bulinus*, is widely distributed, but seldom found, probably because it lives in rainwater pools that carry water during a few months only. Nothing is known of its susceptibility to *Schistosoma*.)

Full-grown shell higher than 7 mm 19

19. Shell thin and rather small, usually not exceeding 10 mm in height; columella thin and fragile, only narrowly reflexed; most specimens aphallic . . . . . *Bulinus (B.) coulboisi* (Bgt.)

(*B. coulboisi* is a species from the lakes and ponds of Uganda and Tanganyika, sometimes resembling *B. truncatus trigonus* and leading to confusion, but always distinguishable by the triangular mesocones. Infected experimentally with *Schistosoma haematobium*.)

Shell usually more solid and when full-grown mostly more than 10 mm high; columella stronger and often broadly reflexed; aphallic specimens extremely rare 20

20. Shell usually very light-coloured, often almost white (but sometimes colour is concealed by a dark coating); when typically developed shell is somewhat cylindrical and columella is rather narrow and slightly twisted . . . . . *Bulinus (B.) tropicus zanzebaricus* (Cl.)

(This is the common form of *tropicus* in small lakes and ponds in Tanganyika. The populations are fairly uniform, but sometimes almost typical *tropicus* may be found.)

Shell darker, brownish, inflated or ovate 21

21. Spire rather high, broadly conical and with rather pointed apex; body-whorl as a rule not inflated 22

Spire very short, sometimes not raised above body-whorl, which is large and frequently somewhat inflated . . . . . *Bulinus (B.) tropicus toroensis* M.-B.

(The subspecies *toroensis* is distributed in the smaller lakes (mainly crater lakes) of western Uganda and Ruanda. A similar form is found in some ponds in western Tanganyika.)

22. Full-grown shell 10-15 mm high; aperture large with regularly curved outer lip and a more or less expanded and reflexed columellar margin . . . . . *Bulinus (B.) tropicus tropicus* (Krauss)

(The nominate form is an extremely variable form which has its distribution in southern Africa from Northern Rhodesia southwards. In some habitats it does not seem to grow larger than 6-8 mm in height. Also a small form with almost flat spire is known. *B. tropicus* and its subspecies do not act as intermediate hosts of *Schistosoma*, but some are known as hosts of *Paramphistoma*.)

Shell slightly larger, up to 17 mm in height, and when typically developed of a more regularly ovate appearance; columella usually a little narrower . . . . *Bulinus (B.) tropicus alluaudi* (Dautz.)

(The subspecies *alluaudi* is also very variable, but, being known from Kenya only, no confusion with the nominate form is possible. A costulate form is known from Athi river and Lake Naivasha.)

23. Central tooth of radula about 30 microns long (Fig. 24); shell almost cylindrical with high and narrow aperture and distinctly twisted columella . . . . . *Bulinus (B.) mutandaensis* (Preston)

(*B. (B.) mutandaensis* is endemic to Lake Mutanda, south-western Uganda.)

Central tooth less than 15 microns long (Fig. 23); shell not cylindrical; aperture broader; columella not twisted 24

24. Sculpture consists of distinct and regular costulation all over the shell . . . . . *Bulinus (B.) truncatus sericinus* (Jick.)

(The true *sericinus* is restricted to the Ethiopian highlands, but a similar form is known from the Nubian Nile. Potential intermediate host of *Schistosoma haematobium*.)

Costulation, if present, restricted to upper whorls 25

25. Full-grown shell usually more than 9 mm high and, as a rule, with rather prominent spire; shell light-yellowish-grey in colour . . . . . *Bulinus (B.) truncatus truncatus* (Aud.)

(The nominate form is widely distributed in northern Africa and the Middle East where it acts as intermediate host of *Schistosoma haematobium*. In eastern Africa it is known only from the Nile valley in the Sudan and northern Uganda.)

Full-grown shell 7-10 mm high; spire very short, often almost or completely flat 26

26. Both animal and shell are dark; lower part of columella oblique . . . . . *Bulinus (B.) transversalis* (Martens)

(*B. (B.) transversalis* is a characteristic small, globular species known only from the northern shores of Lake Victoria and the upper part of the Victoria Nile.)

Colour light yellow or grey; columella straight 27

27. Shell usually inversely coniform with very flat spire (Fig. 9) . . . . . *Bulinus (B.) truncatus trigonus* (Martens)

(The subspecies *trigonus* is known only from Lakes Victoria and Edward, the Victoria Nile, a few dams and streams near Lake Victoria. Potential intermediate host of *Schistosoma haematobium*, but not susceptible to *S. capense*.)

Shell globose with slightly prominent spire and usually rather solid . . . . . *Bulinus (B.) nyassanus* (Smith)

(*B. (B.) nyassanus* is endemic to Lake Nyasa.)

28. Whorls of spire with more or less pronounced shoulder angle (Fig. 17); copulatory organ rather small with vergic sheath of about the same length as preputium . . . . . *Bulinus (B.) forskalii* (Ehrenberg)

(*B. (B.) forskalii* is a very variable species distributed all over Africa south of the Sahara and in Egypt. The variations are mainly in size of the shell and relative length of the spire. It is usually found in small ponds, ditches and temporary pools. Probably susceptible to *Schistosoma haematobium*, but not to *S. capense*.)

No shoulder angle on upper whorls; copulatory organ large, with vergic sheath twice as long as preputium . . . . . *Bulinus (B.) scalaris* (Dunker)

(*B. (B.) scalaris* is a rare species of temporary waters. In eastern Africa known only from a few localities in Uganda, western Kenya and Northern Rhodesia; but probably more common than the few finds indicate.)

29. Larger species with a shell more than 3 mm high (except in very young specimens) 30

Small species, less than 2 mm high 42

30. Shell large and flat, consisting of about 6 whorls which are flat on the upper side (Fig. 12); diameter of umbilicus distinctly larger than height of last whorl; central teeth of radula less than 10 microns long (Fig. 27) 31

Shell relatively higher, consisting of 4-5.5 whorls which are rounded or angular (very seldom flat) on the upper side (Fig. 13); diameter of umbilicus as large as or smaller than height of last whorl; central teeth more than 10 microns long (Fig. 25) 33

31. Vergic sheath distinctly longer than preputium . . . . . *Biomphalaria sudanica rugosa* M.-B.

(The subspecies *rugosa* is known only from the type-locality near Kapalala, Northern Rhodesia. Potential intermediate host of *Schistosoma mansoni*.)

Vergic sheath equal in length to or a little shorter than preputium 32

32. Whorls increase very slowly in width; at a diameter of 15 mm shell consists of 6.5 whorls; umbilicus 1.5 times as large as height of last whorl . . . . . *Biomphalaria sudanica sudanica* (Martens)

(The nominate form is found mainly north of the equator and is fairly common in the Sudan and Uganda. Intermediates between this and the following subspecies are common in southern Uganda and are also known from Tanganyika. Acts as intermediate host of *Schistosoma mansoni*.)

Whorls increase somewhat more rapidly in width; at a diameter of 15 mm shell consists of 6 whorls; umbilicus is about 1.25 times as large as height of last whorl . . . . . *Biomphalaria sudanica tanganyicensis* (Smith)

(This subspecies replaces the nominate form in Tanganyika and south-western Kenya. It is the largest *Biomphalaria*, measuring up to 23 mm in diameter. Intermediate host of *Schistosoma mansoni*.)

33. Diameter of shell at least 2.5 times as great as height; diameter of umbilicus at least two-thirds the height of last whorl 34

Diameter of shell less than 2.5 times as great as height; diameter of umbilicus only about half the height of last whorl or less 39

34. Whorls have a distinct angle on both sides, the upper one being placed almost in middle of whorls, while the basal angle is situated nearer to suture; shell has bright reddish-brown colour and, when fresh, a silky lustre caused by the regular, fine growth lines . . . . . *Biomphalaria angulosa* M.-B.

(This species is distributed from southern Tanganyika to Transvaal, but seems to be rare. Potential intermediate host of *Schistosoma mansoni*.)

Whorls rounded or somewhat flattened on upper side and bluntly angular on under side. Shell greyish, frequently very light, in colour, and growth lines less regular, but colour and sculpture are usually concealed by a grey, brown or black coating. Young shells of 5-7 mm in diameter have in rare cases developed lamellae inside aperture 35

35. Whorls increase rather slowly in width and flattened on upper side; lateral teeth have arrowhead-shaped mesocones . . . . . *Biomphalaria rhodesiensis* (M.-B.)
(The species *rhodesiensis* is known from Northern Rhodesia and Nyasaland. It could easily be confused with *B. sudanica*, but has one whorl less than a *sudanica* of equal size. The narrower umbilicus and the arrowhead-shaped mesocones are also distinctive. Potential vector of *Schistosoma mansoni*.)

Whorls rounded on upper side and more rapidly increasing in width; lateral teeth have simply triangular mesocones 36
(This group comprises the common *Biomphalaria pfeifferi* (Krauss) which is distributed all over Africa south of the Sahara and a number of local forms, all of them proved intermediate hosts of *Schistosoma mansoni*. From a medical point of view there is no reason to deal with the subspecies, but for the sake of completeness the most characteristic are given below.)

36. Marginal teeth of radula have undivided or bicuspid ectocones (Fig. 25); mainly south of equator 37

Ectocones of marginal teeth divided into four minute cusps (Fig. 26); mainly north of equator . . . . . *Biomphalaria pfeifferi rüppellii* (Dunker)
(The subspecies *rüppellii* is widely distributed in eastern Africa from the equator northwards to Eritrea. It is a rather variable form as regards size and shape of the shell.)

37. Copulatory organ relatively large, about two-fifths of diameter of shell; verge usually about half as long as preputium . . . . . *Biomphalaria pfeifferi bridouxiana* (Bgt.)
(This is a very variable form, merging gradually into the other subspecies of *pfeifferi*. Typical *bridouxiana* are known from Lakes Kivu and Tanganyika and adjacent areas.)

Copulatory organ smaller, about one-third of diameter of shell; verge frequently equal in length to preputium 38

38. Verge usually not longer than vergic sheath . . . . . *Biomphalaria pfeifferi pfeifferi* (Krauss)
(The typical form (from Natal) has arrowhead-shaped mesocones on the lateral teeth, but in Transvaal and the two Rhodesias the mesocones are simply triangular, and the nominate form merges here into *B. pfeifferi bridouxiana*.)

Verge as a rule longer than vergic sheath, sometimes even twice as long . . . *Biomphalaria pfeifferi nairobiensis* (Dautz.)
(Common in southern Kenya and northern Tanganyika, the form *nairobiensis* is rather intermediate between *B. pf. bridouxiana* and *B. pf. rüppellii* than a true subspecies. Too little material from eastern and southern Tanganyika has been available for a solution of the question.)

39. Rather large, with shell diameter of 11-13 mm; last third of body-whorl of full-grown shell slopes downwards . . . . . *Biomphalaria smithi* Preston
(Endemic to Lake Edward. Potential intermediate host of *Schistosoma mansoni*.)

Smaller, 7-11 mm in diameter; last part of body-whorl coiled in almost the same plane as other whorls 40

40. Whorls higher than wide; umbilicus very narrow with a diameter of about one-fifth that of shell . . . . . *Biomphalaria stanleyi* (Smith)
(Known only from Lake Albert. Probably intermediate host of *Schistosoma mansoni*.)

Whorls wider than high; umbilicus about one-fourth of diameter of shell . . . 41

41. Angle on under side of whorls placed in middle and projects ridge-like in umbilical cavity; growth lines rather coarse . . . . . *Biomphalaria choanomphala choanomphala* (Mart.)
(Common in Lake Victoria and the Victoria Nile. Intermediate host of *Schistosoma mansoni*.)

Basal angle placed near sutures and therefore not projecting ridge-like in umbilical cavity; growth lines very fine and provide the shell with a silky lustre . . *Biomphalaria choanomphala elegans* (M.-B.)
(Endemic to Lake Albert and the Albert Nile. It hardly acts as intermediate host of *Schistosoma*.)

42. Shell flat or concave on both sides with only slightly embracing whorls (Fig. 14 & 15) 43

Shell lens-shaped or convex above and flat below; whorls deeply embracing (Fig. 16) 44

43. Shell consists of 4-5 slowly increasing whorls (Fig. 14) . . . . . *Anisus*
(Only two *Anisus* species are known from eastern Africa. *A. natalensis* (Krauss) is common and widely distributed.)

Shell consists of 3-4.5 more rapidly increasing whorls (Fig. 15) . . . . . *Gyraulus*
(The commonest species is *G. costulatus* (Krauss). A number of other species are known, mainly from the Great Lakes.)

44 Shell without internal lamellae . . . . . *Lentorbis*
(*L. junodi* (Connolly) is widely distributed, but rather rare.)

Shell has 4-9 sets of internal lamellae . . . . . *Segmentorbis*
(Two common and two rare species are known from Eastern Africa.)