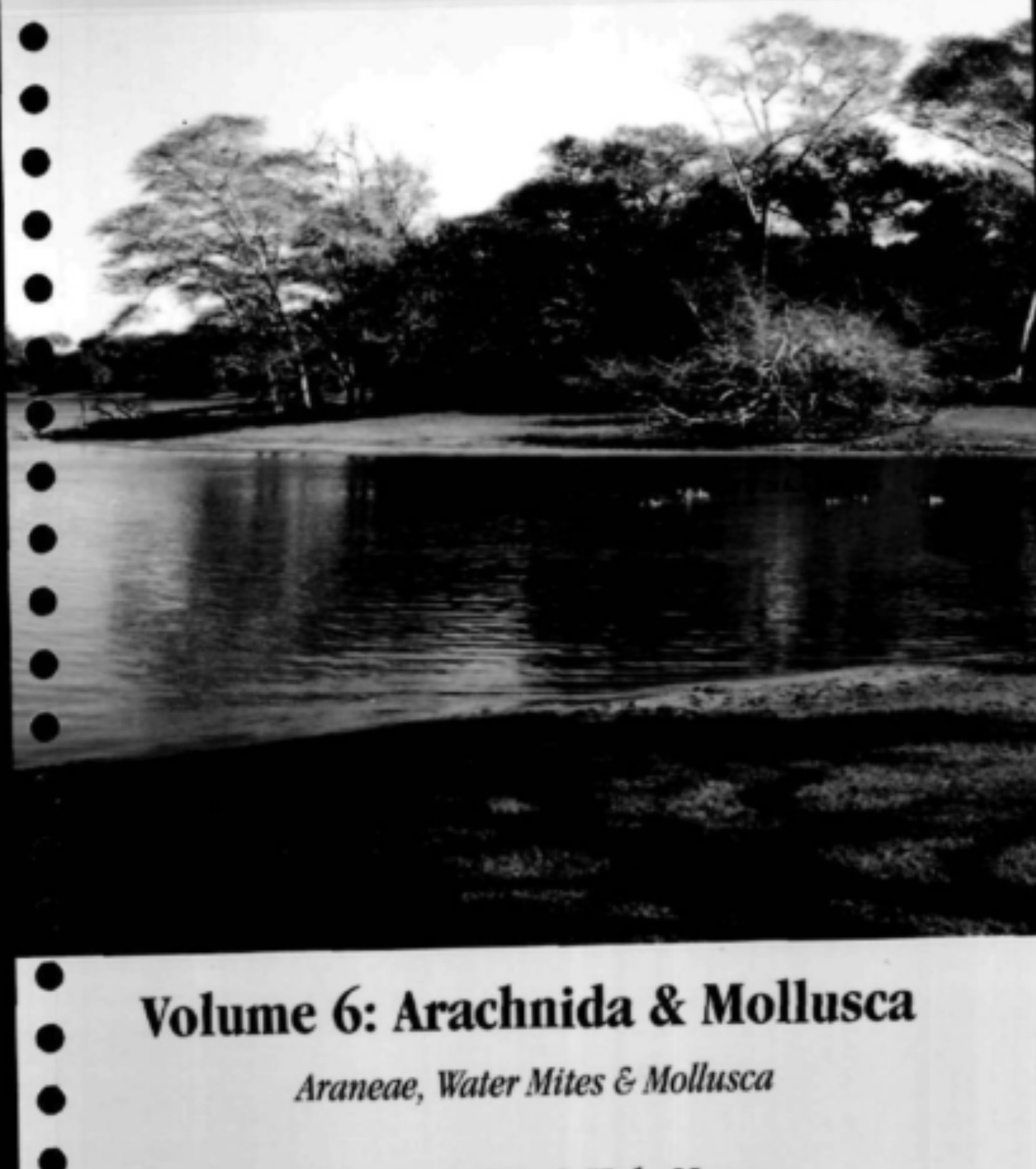
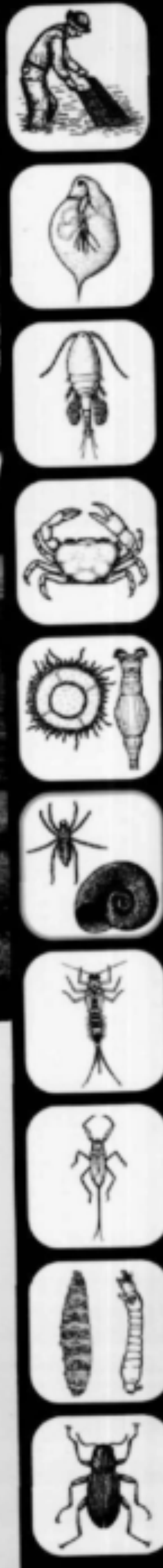
Guides to the

Freshwater Invertebrates of Southern Africa





Volume 6: Arachnida & Mollusca

Araneae, Water Mites & Mollusca

Editors: JA Day & IJ de Moor

TT 182/02

Water Research Commission

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Freshwater Invertebrates of Southern Africa

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Cover photograph: Nyamiti Pan, a floodplain pan on the Pongola River in KwaZulu-Natal by JA Day

Since there is a possibility that revised editions of this series of guides may be printed in the future, we welcome constructive suggestions, particularly in relation to keys used to identify various taxa. These suggestions should be submitted in writing to the Executive Director, Water Research Commission (address given above). All such correspondence must be marked "For the attention of Project K5/916/0/1".

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PREFACE

This identification guide is one of a series of ten books that include keys to most of the fresh- and brackish-water invertebrates in southern Africa. The paucity of identification guides suitable for non-specialists has become a yawning gap in the tools available to scientists, managers and scholars concerned with the assessment and management of water resources. It is hoped that the present guides will be of value to these and other users, and that the environment will benefit as a result. The principle aim of this series is to synthesize much of the existing knowledge on the identification of freshwater invertebrates into a standard format that is accessible to users who wish to identify taxa beyond their field of expertise.

It is a truism that identification guides are perpetually out of date, particularly in terms of nomenclature, due to advances in systematics. To keep abreast with some of the changes in nomenclature, readers are referred to the *Checklist of Aquatic Insects and Mites* (http://www.ru.ac.za/aquatalogue). There is also a possibility that the present series will be revised periodically, but this is contingent on future funding.

Identification of taxa to species level is the ideal to which we would like to strive, but for a number of reasons this is not always possible: the present knowledge of taxa does not often permit such detailed identification, and in instances where taxa are well-known, identification to such a fine resolution is usually constrained by space considerations and cost effectiveness. In some instances, particularly for small, relatively well-researched groups such as the freshwater molluscs, taxa have been identified to species level. Since new species are constantly being discovered, users of these guides are cautioned against attempting to 'make' unusual specimens 'fit' existing keys to species level. Users are encouraged to inform experts of such specimens, to take note of new distribution records, and to lodge all collections with well-known museums, particularly those that are depositories for collections of freshwater invertebrates (e.g. the Albany Museum, the South African Museum and the Transvaal Museum).

This series includes an initial introductory volume containing general information and a key to the families of invertebrates. Subsequent volumes contain keys to different invertebrate groups, most often logically clustered together but in some instances the need for cost-effectiveness has resulted in the creation of some rather uncomfortable 'bedfellows', such as the arachnids and molluscs that are combined in this volume.

It should be noted that references have been limited to key publications that will assist the reader in finding valuable sources of information. They are, therefore, referred to as 'Useful References' and may include some publications not cited in the text.

The books in the series are the culmination of years of effort by a large number of people and organizations: Shirley Bethune, Jenny Day, Barbara Stewart, Nancy Rayner and Maitland Seaman started the project in 1986; Jenny Day, Bryan Davies and Jackie King initiated contact with authors and began the editing process, and Barbara Stewart and Elizabeth Louw later became involved in editing the Crustacea chapters. A decade later, Chris Dickens successfully obtained funding from the Water Research Commission (WRC) for the completion of the project, and later took on the job of Project Leader; Steve Mitchell managed the project from the WRC; Jenny Day took on the role of senior scientific editor, and Irene de Moor was contracted as managing editor from 1998. All of those above (with the exception of Nancy Rayner and Elizabeth Louw) as well as Mark Chutter, Ferdy de Moor, Lil Haigh, Arthur Harrison, Rob Hart, and Martin Villet, are part of the Editorial Board that was initially formed in 1998.

Numerous authors, including those in this book, have contributed time and expertise towards the drafting of the keys. The authors have not been paid for their efforts, which were given in the true spirit of science and a love of their work. A small donation from the Zoological Society of South Africa helped to initiate this project, but the series is largely a product of the Southern African Society of Aquatic Scientists (SASAQS), whose members are acknowledged for their support.

Umgeni Water, the Albany Museum, the Freshwater Research Unit (University of Cape Town), the South African Museum and the WRC have given organizational support at various stages of the publication.

Chris Dickens, Steve Mitchell & Irene de Moor

ACKNOWLEDGEMENTS

The publication of this series of guides would not have been possible without the enormous effort and dedication of a number of people and organizations who have been mentioned in the Preface.

The following people and organizations are also acknowledged for their assistance in the production of this book: Ferdy de Moor, Fred Gess, Sarah Gess and Helen James of the Albany Museum for providing constant advice on editorial and technical details relating to the systematics of freshwater invertebrates; Charmain Wynne for doing much of the page-setting; Nikki Köhly for her excellent drawings of invertebrates and Nancy Bonsor for her assistance in tracing and touching up figures; Bronwyn Tweedie, Debbie Brody and John Keulder of the Graphics Services Unit, Rhodes University, for drawing the maps and producing bromides, and Drinie van Rensburg of the WRC for her advice on printing and text layout.

Chapters 2 and 3, on the water mites and the Mollusca respectively, are updated versions of previous publications, and the original publishers are thanked for allowing us to make use of previous copy (see pages 39 and 116 for detailed acknowledgements).

Further acknowledgements pertaining to particular chapters in this volume are given at the end of the chapters concerned.

GEOGRAPHICAL REGION COVERED BY THIS GUIDE

This series of invertebrate guides covers the southern African region, defined as 'south of (and including) the Cunene Catchment in the west and the Zambezi Catchment in the east' (Fig. 1). Distribution records from further afield are, however, sometimes included for various reasons, particularly in cases where keys to particular groups have historically been composed to cover a wider region in Africa. The greatest collection effort has, however, focussed on catchments south of the Limpopo River, so the emphasis has fallen naturally on this region.

Collection efforts relating to most groups of freshwater invertebrates fall far short of adequate coverage. Consequently, locality records of many taxa are patchy and cannot be regarded as a good reflection of actual

Fig. 1. Southern Africa: the region covered by this series of invertebrate guides.

KEY: The dark dashed line represents the northern boundary of the Cunene Catchment in the west and the Zambezi Catchment in the east.

distributions. For this reason the term 'records' has been used in preference to 'distribution'.

It is hoped that this series of guides will stimulate a greater collection effort, which will in turn lead to the upgrading of geographical information on the diversity of freshwater invertebrates in southern Africa. In order to avoid meaningless references to place names such as the ubiquitous 'Rietfontein', all records are related to countries, provinces or acceptable regional names. To avoid the confusion which often arises in association with regional names, a 'Glossary of place-names' has been compiled (see page 133), and a map of the new provincial boundaries in South Africa is given below (Fig. 2).

Fig. 2. The new provincial boundaries of the Republic of South Africa

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INTRODUCTION

ARACHNIDS AND MOLLUSCS

by

J.A. Day

For convenience, this volume deals with two disparate groups of invertebrates, the molluscs and the arachnids. Apart from them both being invertebrate taxa, probably the closest feature they have in common is that neither is as significant in fresh waters as it is elsewhere. The molluscs are more speciose and of greater ecological significance in the sea than they are in fresh waters, while most arachnids are terrestrial.

FRESHWATER MOLLUSCS

While the freshwater molluscan fauna of the African Great Lakes (particularly Lake Tanganyika), and of the African tropics in general, is very speciose, that of the more southern regions is not. Indeed, for reasons as yet not entirely explained, there is a gradient in the number of species from south to north even within the region. We know that few molluscs can survive in the very soft, pure, acidic, calcium-poor waters of the south-western corner of the continent; we also know that most of those that do occur in this region are physically small and have thin, calcium-poor shells. We also know that of the 40 or so genera and 100 or so species in 22 families known from the region, only about 25 species in 8 genera and 7 families have been recorded from the Western Cape. Interestingly, indications are that three of those eight genera represent species flocks, implying genetic isolation and adaptive radiation within the fynbos region.

The chapter on molluscs was first written as a separate book (Appleton 1996), published by the University of Natal Press. One of the main objectives of that volume was to provide information on molluscs as vectors of a variety of flukes parasitic on mammals, especially humans. Since the present series of volumes is designed for the identification of freshwater invertebrates in general, the parasitological connection has been played down in this chapter. We are delighted to have been given the opportunity to re-issue the appropriate sections of that volume in updated form.

Recognition of freshwater molluscs

Of all freshwater invertebrates, molluscs are some of the easiest to recognize because they all have one or two shells. Gastropods are the snail- and limpet-like forms; bivalves, as the name implies, are clam- or mussel-like forms with two shells. A word or two of caution are necessary for those collecting samples of invertebrates that include molluscs: the shells, especially of the smaller forms, are often very brittle and the larger basal whorls can be damaged, so that specific characteristics may not be easy to see. Further, since unbuffered formalin is acidic, if specimens are preserved or stored in formalin the shells of molluscs may become very eroded.

FRESHWATER ARACHNIDS

One of the great groups of arthropods is the Chelicerata, which includes the familiar spiders, ticks and mites, as well as more bizarre forms like the solifuges or jerrymunglums (what a beautiful word!), the harvestmen, and the horseshoe 'crabs'. Of these, horseshoe crabs of the genus *Limulus* are not crabs at all, but the sole survivors of an ancient group of marine chelicerates known as the Xiphosura. All the rest are included in the class Arachnida; with few exceptions, all are terrestrial.

Only two groups of arachnids can lay any claim to being aquatic. The first is the spiders, by virtue of the fact that some species, across a variety of families, are associated with water. Even within this group, most are essentially terrestrial, although they feed on submerged or emerging aquatic invertebrates or even on fish. Indeed the common name of one family is the 'fishing spiders'. A few spiders make silken nests under the water, but this is not common.

The second group of aquatic arachnids is the water mites or 'hydracarines'. Mites, which form the arachnid order Acarina, are very common micropredators, herbivores, detritivores and parasites in terrestrial ecosystems. In the suborder Trombidiformes, which includes many species of plant parasites, a few families are found exclusively in fresh waters and together are commonly known as the *hydracarines*. (The word 'Hydracarina' has been used in the past as a taxonomic term but it no longer has any formal meaning.) A single family, the Halacaridae, contains several genera of marine and estuarine mites. Most hydracarines are freeliving as adults, although at least one larval stage is parasitic in aquatic invertebrates, usually insects. Members of the family Unionicolidae, however, are parasitic in freshwater mussels throughout their lives.

Members of another suborder of mites, the Cryptostigmata, normally live in soils and, because they are hard-bodied and darkish in colour, are often known as beetle mites. A few species in the genus *Hyrdozetes*, in the family Eremaeidae of the division Oribatei, are found in fresh waters. Although it seems that none has yet been described from southern Africa, several apparent species are fairly commonly collected in vleis and rivers of the south-western Cape (pers. obs.).

Collating the data from the world hydracarine literature, Arthur Harrison (pers. comm.) indicates that about 160 species in 66 genera and 19 families are known for the southern African region. It seems that virtually no specific collecting of water mites has been done in the region, so records are sporadic and distributions are almost certainly wider than the literature suggests. As things stand at the moment, 116 of the 160 species have been recorded from a single region. Table 1 indicates the number of species known from each of the regions within southern Africa where water mites have been recorded. The apparently high levels of endemism are almost certainly artefacts of sporadic and unsystematic collecting.

In this volume Jansen van Rensberg uses Cook's (1974) subordinal taxonomy, which recognizes seven superfamilies and about 44 families. Referring to the hydracarine fauna of the USA, however, Pennak (1989) has "... the impression that specialists have been too anxious and zealous to establish new 'families', many of which are 'ill-defined'."

Table 1. Species of water mites recorded from southern Africa (data available only for pre-1994 provincial boundaries)

Region	Number of species recorded	Number of species known from this region only
W. Cape	66	34
E. Cape	23	13
Natal	23	6
Transvaal	78	47
Zimbabwe	20	14
Mozambique	2	2

Recognition of freshwater arachnids

Adult mites and spiders are easy to recognize because they have four pairs of walking legs, two pairs of mouthparts, and an unsegmented body; they are easy to distinguish from each other because even the smallest spiders likely to be encountered in fresh waters are much larger than the biggest mites. Should there be any doubt, the body of a spider is divided into anterior and posterior sections by a narrow 'waist', whereas the bodies of mites are undivided.

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CHAPTER 1

ARANEAE

by

A. S. Dippenaar-Schoeman

Araneae (spiders) are a diverse group of land animals. They belong to the class Arachnida, a group of animals that is characterized by having four pair of legs and only two body regions—a cephalothorax and an abdomen. Compared to insects they are without antennae or wings. The class Arachnida comprises 11 living orders and five extinct orders, of which nine orders occur in southern Africa. Only members of the Acari (mites) and Araneae (spiders) contain species that are closely associated with fresh water.

Southern Africa has a rich fauna of spiders that are represented by 67 families and about 2000 species. Spiders are found in almost every ecological niche on land, and a small group—represented by three families and about 20 species—is associated with fresh water.

Habitat preferences

Spiders commonly associated with fresh inland streams, rivers, swamps and lakes can be divided into two groups:

* *True aquatic spiders*: spiders that spend most of their lives below the water surface. An air bubble, shaped like a diving bell, is made below the water surface and is used as a permanent retreat to live in. A single species, *Argyroneta aquatica* Clerck (Argyronetidae), is known, but only from Europe.

* *Semi-aquatic spiders*: spiders that spend all their lives in or around water.

Spiders can be divided into two main guilds, namely web-dwellers and free-living wandering spiders. In southern Africa, two families of wandering spiders (the Pisauridae and Lycosidae) contain species that are semi-aquatic and associated with fresh waters. They are the fish-eating spiders in the genus *Thalassius* (Pisauridae) and some species of wolf spiders (Lycosidae) in the genera *Pardosa*, *Pirata*, *Proevippa* and *Wadicosa*. The web-dwellers associated with fresh water make their webs over or close to the water edge in swamps, standing pools or reservoirs. The most common web-dwellers associated with fresh water belong to the subfamily Tetragnathinae of the Tetragnathidae. All members of the genus *Tetragnatha*—also known as the large-jawed, orb-web water spiders—are found near standing waters. Members of a second genus, *Leucauge* (not included in this text), known as the silver vlei spiders, are usually found in wetlands but are not always associated with standing waters. They are easily recognized by their bright silver, gold, red and green patterns on their bodies.

Feeding

Spiders are predominantly predators. They are mostly polyphagous but some are prey specialists. All instars feed actively. Their prey includes a variety of small animals such as insects, other arachnids, amphibians and fishes. The web-dwellers use silk threads to construct intricate webs to catch their prey, while the wandering spiders have abandoned the use of a web and overpower their prey with speed and the use of their legs and chelicerae.

Reproduction

Mating usually takes place in spring after the male and female have reached maturity. Males use small sperm webs to transfer sperm from their genital openings to their secondary copulatory organs (on the palp), where the sperm is stored until mating takes place. Intricate mating rituals, which vary between species, form part of the mating process. Eggs are usually deposited in a waterproof egg cocoon made of silk. More than one egg cocoon is produced per season. The number of egg cocoons and eggs produced by the different spider families varies greatly. The egg cocoons are deposited on the substrate or in a retreat or are carried around by the female, either attached to her spinnerets (as in the Lycosidae: Fig. 1.2F), or below her body (as in the Pisauridae: Fig. 1.2E). Only a small proportion of the offspring survive to maturity.

As young spiders grow they undergo a number of moults. The first moult (instar 1) takes place in the egg cocoon, and when the spiderlings (instar 2) emerge they closely resemble the adult in all but size. Individuals of small species may moult only three to four times during their lives, but those of larger species go through nine to ten instars before reaching maturity. Since a large number of spiderlings emerge from the egg cocoon simultaneously, local overpopulation can become a problem, resulting in competition for available food and cannibalism. Some spiderlings simply walk away to settle elsewhere, but many disperse in a unique way, in a process called 'ballooning' whereby air currents are used to carry young spiders away. Spiders of the families associated with fresh water live from 9 to 18 months. They overwinter in the egg cocoon or as immature spiderlings, mature in spring, mate during summer, and die in late summer.

Locomotion

The semi-aquatic spiders are able to move over the water surface. Movement on the water is mainly by means of the second and third pair of legs, while the front pair of legs are stretched out in the air and serve as 'feelers'. The fourth pair of legs are dragged behind. These spiders can also dive below the water surface or crawl down the stems of water plants or down rocks in pursuit of prey, or when trying to escape danger. They can stay below the water surface for periods of 5 to 60 minutes using air that adheres to the body setae for respiration. Feeding and reproduction usually take place on land.

Distribution

Most species associated with fresh water are widely distributed throughout southern Africa and are found in water grass, on emergent rocks, or on the water surface of any fresh standing water.

Collection and preservation

Spiders are easily picked off substrates by hand or collected by sweeping a hand-held net through vegetation. Nets can also be used to scoop spiders from the water surface. Specimens are best fixed in 70 % ethyl alcohol. Only adult males and females can be used for species identification.

Morphology

Spiders are distinguished from the other arachnids in having **abdominal silk glands** that produce silk, **cheliceral venom glands** and **fangs**, and secondary copulatory organs on the **male palps**. Species vary considerably in size, shape and colour. The **cephalothorax** is connected to the unsegmented abdomen by a thin **pedicel** (Fig. 1.1B). The dorsal portion of the cephalothorax is known as the **carapace**. There are eight legs attached to the cephalothorax, each consisting of seven segments (Fig. 1.1A). Most spiders have eight simple eyes, while some have six and others two. The eyes are arranged in two (Fig. 1.1A) or three rows (Fig. 1.2D) and the size and pattern of arrangement vary between families and genera.

Spiders have two **chelicerae**, each consisting of a stout basal segment (Fig. 1.1B) and a smaller, movable distal section, the fang, with the **venom duct** opening on the tip. The fang rests in the **cheliceral furrow**, which is often armed on both margins with **teeth** (Fig. 1.2C) known as the **promarginal** and **retromarginal teeth**. The sizes and lengths of chelicerae and fangs differ between families. In a few families, like the Tetragnathidae, the chelicerae are very well developed—hence their common the 'long-jawed, orb-web water spiders'. In the males the cheliceral teeth are frequently enlarged (Fig. 1.2C) and have strong projecting **spurs** dorsolaterally near the fang base, known as **mating apophyses** (Fig. 1.6C). These apophyses (or 'spurs') are used during the mating process. The cheliceral teeth near the base of the fang are frequently enlarged and known as the **guide** teeth. The fangs of most spiders are usually short to medium-long, narrowing towards the tip. In a few families, like the Tetragnathidae, the fangs are very long, frequently curving, or with small humps known as **cusps** (Fig. 1.6C). The **palps,** situated on both sides of the chelicerae, are leg-like and tactile (Fig. 1.1A). In the male the last segment of the palp (the tarsus) is modified into a **secondary copulatory organ** and can be either simple or complex in structure (Fig. 1.2G). The male stores the sperm in the copulatory organs until mating takes place. The shape of the genitalia is usually species-specific and is important for species identification. In the female the **epigynum**, a sclerotized structure with openings to the internal genitalia, is situated between the **book lungs** on the underside of the abdomen (Fig. 1.1B, Fig. 1.4). The abdomen varies in shape, size and colour between families and genera. It is usually round to oval but in several families it is elongated (as seen in the tetragnathids, e.g. Fig. 1.2B). It is frequently decorated with a pattern (Fig. 1.3A–E), or bears structures such as humps (Fig. 1.5B, G), and it can sometimes extend posteriorly beyond the **spinnerets** (Fig. 1.5E). The spinnerets—either four or six in number—are present at the posterior end of the abdomen.

The **length** of a spider refers to the body length excluding the legs and the chelicerae (see Fig. 1.1B).

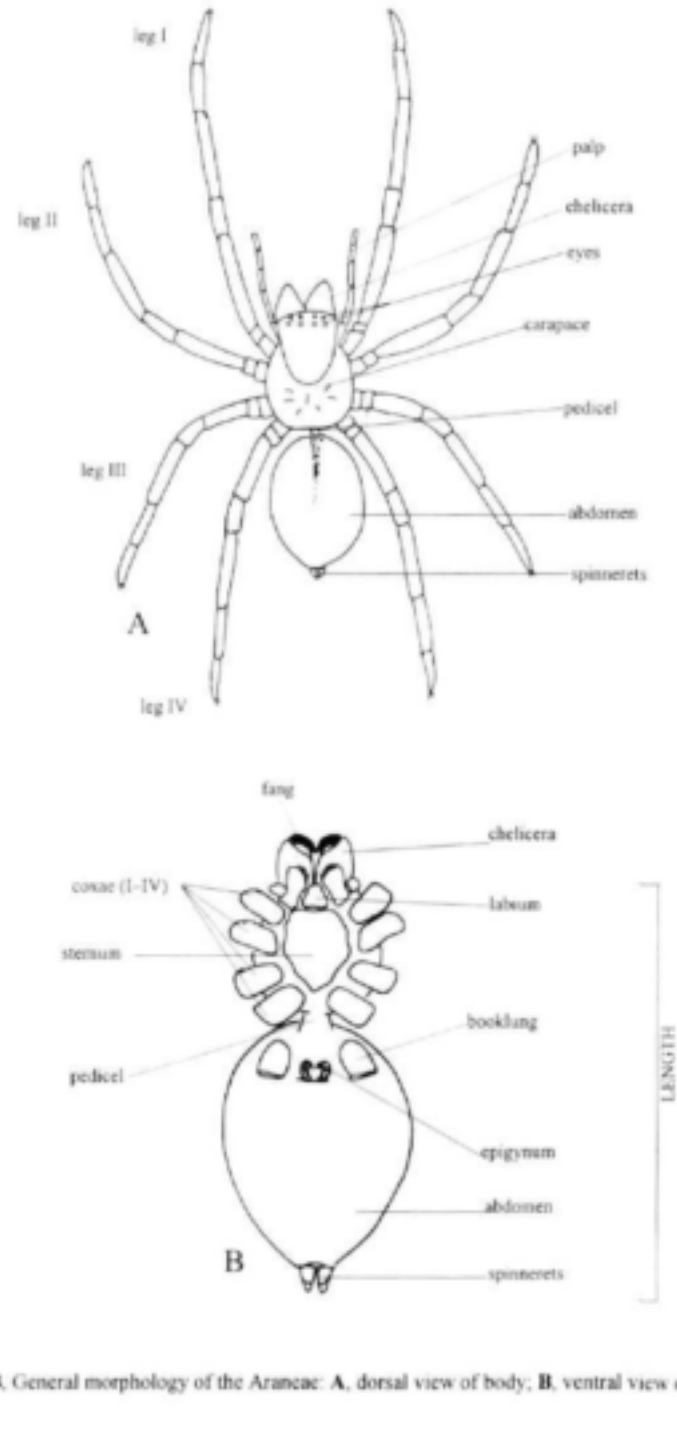

Fig. 1.1. **A–B**, General morphology of the Araneae: **A**, dorsal view of body; **B**, ventral view of body.

KEY TO THE SOUTHERN AFRICAN SPIDERS FAMILIES ASSOCIATED WITH FRESHWATER

1. Body elongated and narrow (Fig. 1.2A), resembling a piece of grass; legs long and slender with the third pair much shorter than the other legs (Fig. 1.2B); chelicerae strongly developed with rows of large teeth (Fig. 1.2C); web an orb made over water.......................................**Tetragnathidae** (p. 16)
– Body oval, legs stronger; third pair of legs not much shorter than the others; chelicerae relatively small and lacking large teeth; wandering spiders (i.e. don't have webs) 2

2. Eyes in two rows, anterior median eyes slightly smaller than posterior median eyes; body decorated with distinct white bands or spots (Fig. 1.3A–E); medium to large spiders (length 8–28 mm); females carry egg cocoon below body (Fig. 1.2E)..**Pisauridae** (p. 10)
– Eyes in three rows, with four small eyes in the front row, two larger eyes in the second row and two medium-sized eyes in the third row (Fig. 1.2 D); carapace with dark bands, abdomen with chevron pattern, bands or white spots (*Pirata* spp.); small to medium-sized spiders (length 5–15 mm); females carry egg cocoon attached to spinnerets (Fig. 1.2F)...........**Lycosidae** (p. 14)

Pisauridae

Subfamily **Thalassinae** (fish-eating spiders)

Figs 1.2E, 1.3A–E, 1.4 A–E

The Pisauridae are a fairly large family of spiders comprising 54 genera. Only genera of the subfamily Thalassinae are associated with fresh waters in southern Africa. Species in the genus *Thalassius* are commonly known as fish-eating spiders and inhabit the fringes of freshwater pools (Abraham 1923; Lawrence 1970; Sierwald 1987, 1988).

Members of the *Thalassius* genus are large (length > 20 mm) powerful spiders, distinguished by the following characters: the carapace is slightly longer than wide and narrower in the eye region (Fig. 1.3A); the eyes are small and in two recurved rows consisting of four eyes each; the anterior eyes in most species are smaller than the posterior median eyes; the cheliceral furrow has three teeth on the retromargin; the abdomen is oval-elongate, tapering towards posterior end (Fig. 1.3A); the legs are strong with leg III the shortest; the colour is variable from yellow to dark reddish brown; the body is densely covered with short hair; dorsally the body has colour patterns consisting of white bands or spots (Figs 1.3A–E).

Species of *Thalassius* are widespread and commonly encountered throughout Africa south of the Sahara (Sierwald 1988). They overwinter from May to September under rocks or logs near the water. They are active during the summer months from October to May; adults are found from November to March and juveniles from April to May. They favour slow-moving streams with dense fringing vegetation. They can walk as well on water as on land. They rest with the tips of their legs, or sometimes the entire body, on the water surface (Foelix 1996). They are able to run with speed, and can even overpower smaller insects while on the surface of the water. To catch larger prey items, such as small fish and tadpoles, a

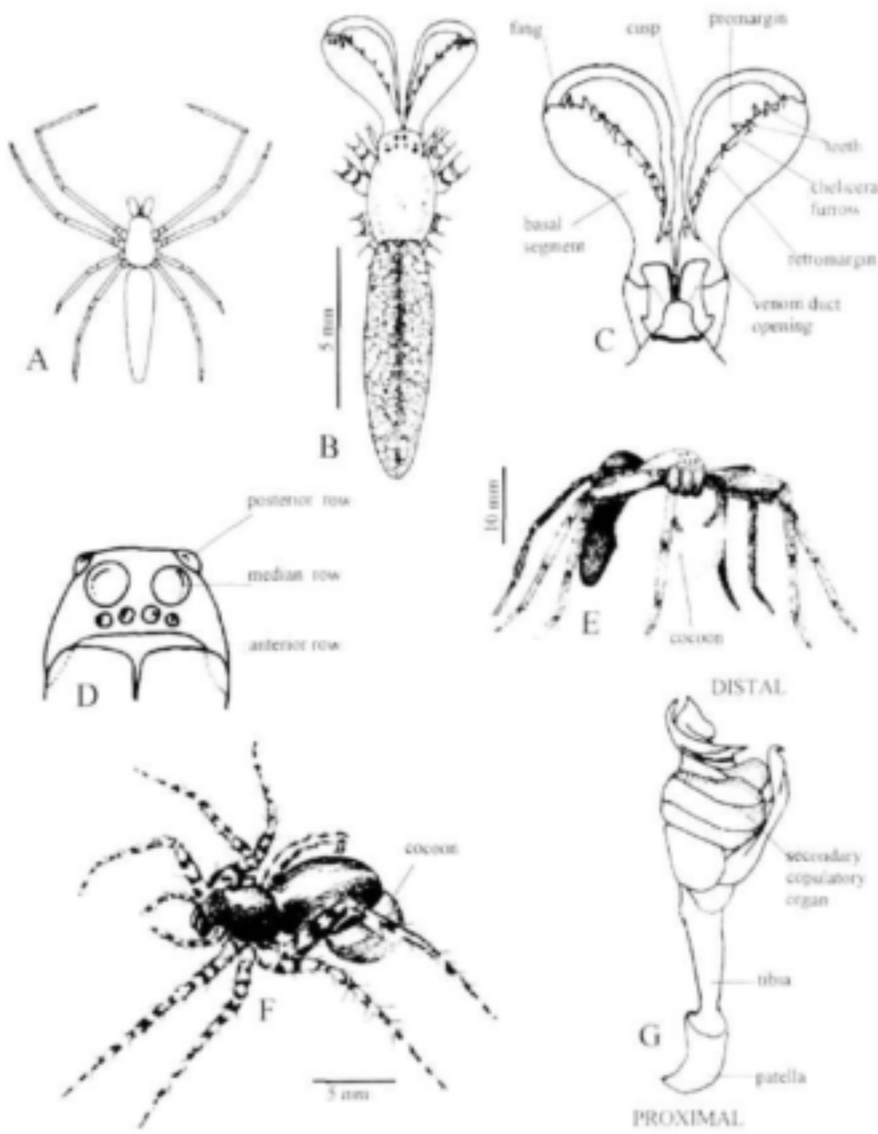

Fig. 1.2 Distinguishing characteristics of various araneid families. **A–C**, Tetragnathidae, *Tetragnatha* sp., **A**, line drawing showing general body shape and relative lengths of legs; **B**, dorsal view of body (with legs truncated); **C**, chelicerae, ventral view; **D**, Lycosidae: eye pattern, anterior view. **E**, Pisauridae: female carrying egg cocoon below body. **F**, Lycosidae: female carrying egg cocoon attached to spinnerets. **G**, Tetragnathidae: *Tetragnatha* sp., distal portion of the male palp. (A after Dippenaar-Schoeman & Jocqué 1997)

spider anchors its posterior legs to water plants or to the margin of the river bank. The front legs are then fanned out, with only the tips resting lightly on the surface. The spider will stay motionless in this position, waiting for prey below the water surface to pass within reach. The spider probably has the ability to sense vibrations in the water as a means of locating prey. It then rapidly dives beneath the surface and uses its legs and chelicerae to grab the prey, which is pulled out of the water before feeding begins.

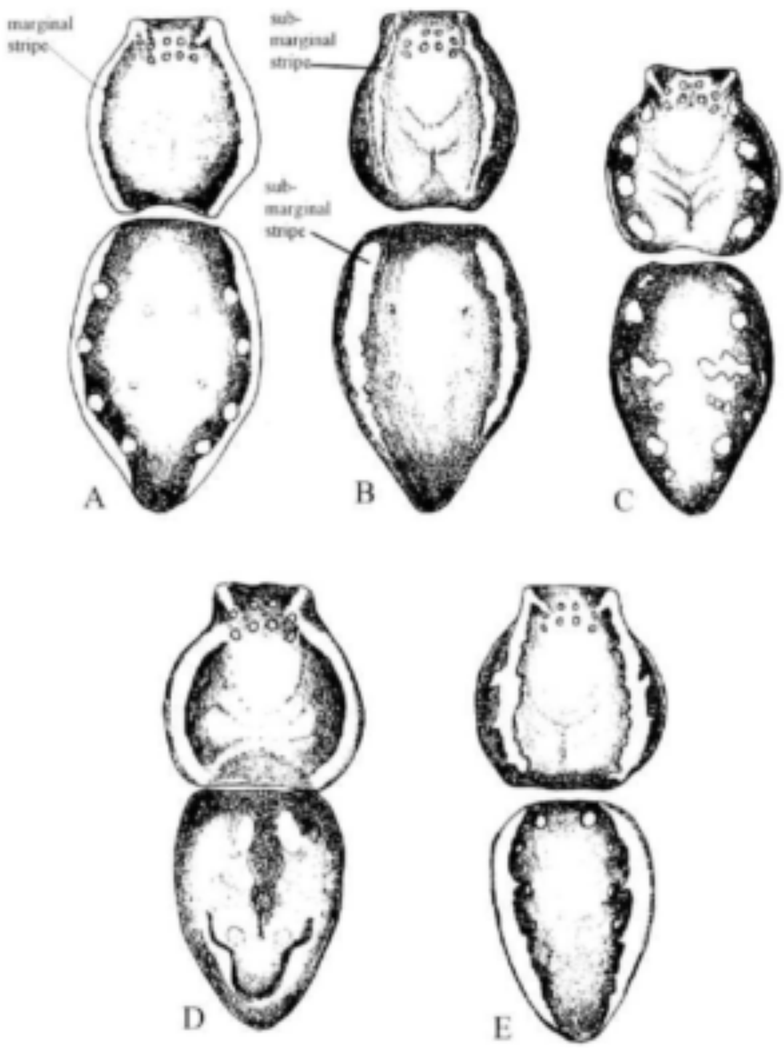

Fig. 1.3 A–E, Pisauridae, *Thalassius* spp., dorsal view of body of female. **A**, *T. margaritatus*; **B**, *T. massajae*; **C**, *T. radiatolineatus*; **D**, *T. rossi*; **E**, *T. spinosissimus* (Drawings after Sierwald 1987).

Abrahams (1923) observed that spiders in the genus *Thalassius* feed on the tadpoles of some species (e.g. *Bufo carens* and *Xenopus laevis*) and on small adult frogs of the species *Hyperolius marmorata* and *Bufo regularis*. Lawrence (1970) also observed members of *Thalassius* spp. preying on small fish (e.g. *Barbus* spp.) as well as on freshwater shrimps, insects and small toads.

A checklist of *Thalassius* species in southern Africa, as well as their distributions and size ranges, is given in Table 1.1.

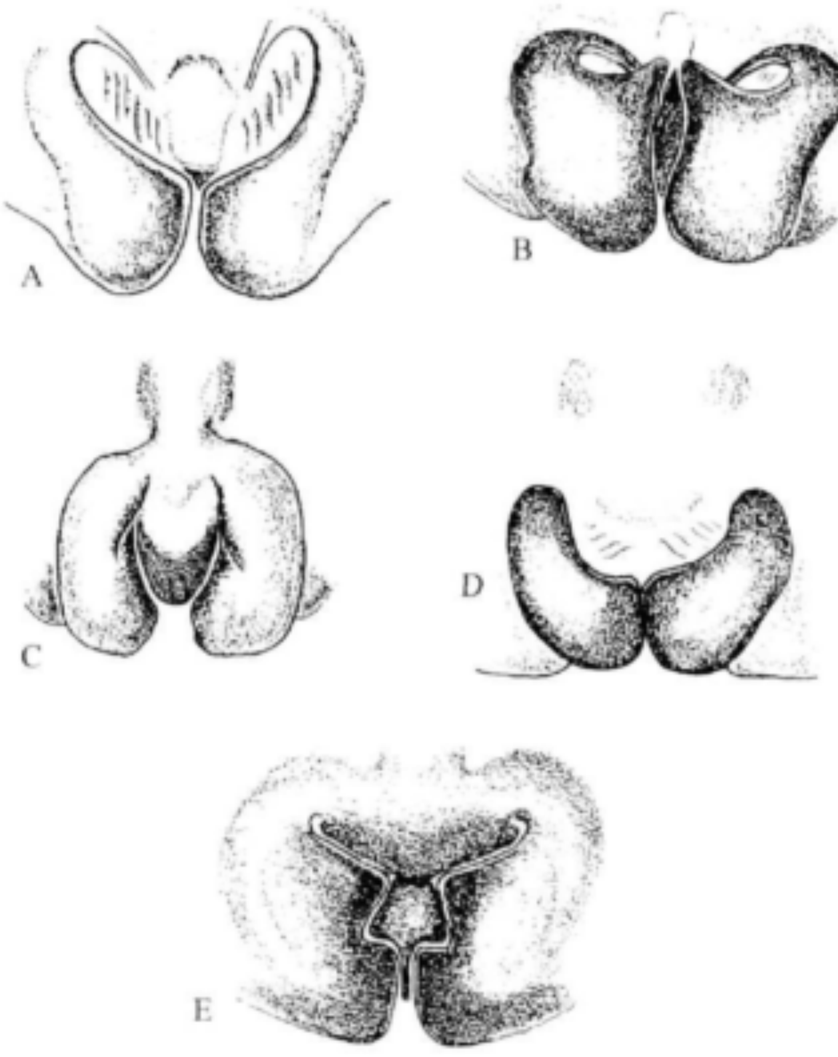

Fig. 1.4. A–E, Pisauridae, *Thalassius* spp., ventral view of female epigynum: **A**, *T. margaritatus*; **B**, *T. massajae*; **C**, *T. radiatolineatus*; **D**, *T. rossi*; **E**, *T. spinosissimus*. (Drawings after Sierwald 1987)

Table 1.1. Species of *Thalassius* (Pisauridae) associated with fresh water in southern Africa. Data compiled from Sierwald (1987). (Size = body length, excluding legs and chicliceræ).

Species/Size	Diagnostic characters	Distribution
Thalassius margaritatus Pocock, 1898 female = 11.5–22 mm male = 12.5–16 mm	Carapace with white marginal bands; abdomen with white marginal bands and row of spots (Fig. 1.3A); epigynum as in Fig. 1.4A.	South Africa: KwaZulu-Natal, Mpumalanga, North-West Province.
Thalassius massajae (Pavesi, 1883) female = 14–21 mm male = 13.3–16 mm	Carapace and abdomen with white submarginal bands (Fig. 1.3B) or sometimes with transverse dark bands; epigynum as in Fig. 1.4B.	Namibia and South Africa: Eastern Cape, KwaZulu-Natal, Limpopo.
Thalassius radiatolineatus Strand, 1906 female = 16–21.5 mm male = 18–20 mm	Carapace variable with white marginal bands or spots (Fig. 1.3C); abdomen with white spots (Fig. 1.3C) or dark bands; epigynum as in Fig. 1.4C.	Zimbabwe, Namibia and South Africa: Free State, KwaZulu-Natal.
Thalassius rossi Pocock, 1902 female = 9.8–19.5 mm male = 8.3–17 mm	Carapace with broad dark median band and white marginal bands; abdomen with heart mark, white spots and dark marking posteriorly (Fig. 1.3D); epigynum as in Fig. 1.4D.	Zimbabwe and South Africa: KwaZulu-Natal.
Thalassius spinosissimus (Karsch, 1879) female = 11.5–27.5 mm male = 9.5–18 mm	Carapace with white submarginal bands; abdomen variable with white spots or white marginal band (Fig. 1.3E); epigynum as in Fig. 1.4E.	Widely distributed throughout the sub-Saharan region. In South Africa, found in KwaZulu-Natal.

Lycosidae (wolf spiders)
Fig. 1.2D, F

Of the wolf spiders (Lycosidae) only four genera—*Pardosa*, *Pirata*, *Proevippa* and *Wadicosa*—contain species that are associated with fresh water in southern Africa. Lycosids are distinguished by the following characteristics: the carapace is longer than wide (Fig. 1.2F) and narrower and higher anteriorly; eight eyes are arranged in three rows, the four eyes in the first row being much smaller than those in the second and third rows (Fig. 1.2D); the abdomen is oval; the legs are of moderate length with three claws; the colour is cryptic, ranging from dull yellowish brown to grey or almost black with darker broad bands on the carapace; the abdomen is frequently adorned with spots or chevron-patterned marks.

The species discussed here are semi-aquatic and are frequently encountered on the banks or stony beds of rivers and ponds or on the water surface, where they are able to move with great agility. Movement consists of a series of gigantic leaps made over the water surface (Lawrence 1964). The smaller, 'lightweight' species of *Pardosa* raise their bodies high above the water. When disturbed they are able to dive below the water surface, clinging to rocks or water plants.

Wadicosa manubriata, which occurs throughout South Africa, has strictly semi-aquatic habitat requirements (Lawrence 1964). All the species of *Pirata* are semi-aquatic and found in the vicinity of water, frequently below the water surface, clinging to aquatic plants. When disturbed they quietly disappear below the water surface. *Pirata trepidus* has been collected from 'water lettuce' (*Pistia stratiotes*), an aquatic weed, in the Letaba River (Kruger National Park). Individuals of this species can remain under water for up to an hour. Their bodies become shiny from the air bubbles trapped in the body hair. They make flimsy silk retreats beneath the leaves and individual spiders have been observed living in close proximity to each other, frequently touching and sharing prey.

During the spring and summer female wolf spiders can easily be recognized by the round, creamish-white egg cocoon that they carry attached to their spinnerets (Fig. 1.2F). After emerging from the egg cocoon, the young spiders climb onto the female's abdomen where they are carried for a few days. Lycosids prey on a variety of small crawling and jumping insects, as well as on other invertebrates.

The taxonomy of the Lycosidae is in a state of chaos and keys to genera are not available. A list of lycosid species that are associated with freshwaters, has been compiled from the literature (Table 1.2).

Table 1.2. Genera and species of the family Lycosidae associated with fresh waters in southern Africa

Genus	Species	Distribution
Pardosa	*P. crassipalpis* Purcell, 1903. *P. potamophila* Lawrence, 1927	Wide spread, throughout southern Africa. Kunene River
Proevippa	*P. hirsuta* (Russell-Smith, 1981)	South Africa: KwaZulu-Natal (Drakensberg Mountains); Lesotho (Maluti Mountains)
Pirata	*P. oneilli* Purcell, 1903 *P. trepidus* Roewer, 1960	South Africa: Mpumalanga, Northern Province. Zimbabwe
Wadicosa	*W. manubriata* (Simon, 1892)	Widespread throughout South Africa.
	W. oncka (Lawrence, 1927)	East, West and Southern Africa: Botswana, Namibia, South Africa

Tetragnathidae

Tetragnatha (long-jawed, orb-web water spiders)
Figs 1.2A–C, F, 1.5A–J, 1.6A–J, 1.7A–I, 1.8A–E, 1.9A–E

Members of the genus *Tetragnatha* are distinguished by the following characteristics: the carapace is much longer than wide (Fig. 1.2B); the eight eyes are small and in two rows of four; the chelicerae are long and well-developed (Fig. 1.2C) with numerous teeth on the cheliceral furrows; the males usually have strong projecting spurs (mating apophyses) dorsally on the chelicerae (Fig. 1.6C, D), their fangs are very long and are sometimes curved, or have small cusps; the abdomen (Fig. 1.5A–J)

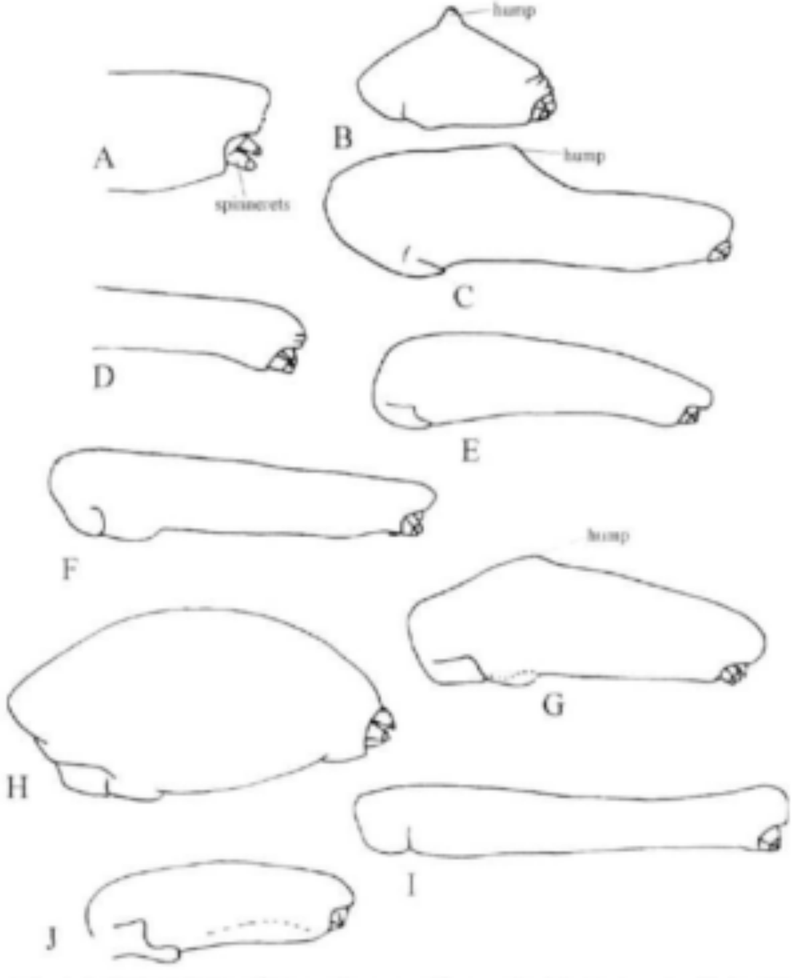

Fig. 1.5 **A–J**, Tetragnathidae, *Tetragnatha* spp., abdomens in lateral view: **A**, *T. boydi* (male); **B**, *T. ceylonica* (immature); **C**, *T. ceylonica* (female); **D**, *T. demissa* (male); **E**, *T. jaculator* (female); **F**, *T. maxillosa* (female); **G**, *T. nitens* (female); **H**, *T. subsquamata* (female); **I**, *T. unicornis* (male); **J**, *T. vermiformis* (female). (Drawings after Okuma & Dippenaar-Schoeman 1988).

varies in shape from elongate to oval, and sometimes has a small hump; the legs are long and slender.

Spiders of the subfamily Tetragnathinae construct their radiating orb-webs near or above slow-moving streams or ponds, usually in sunlit areas. The webs consist of an open hub and 30–40 viscous spirals. The web is

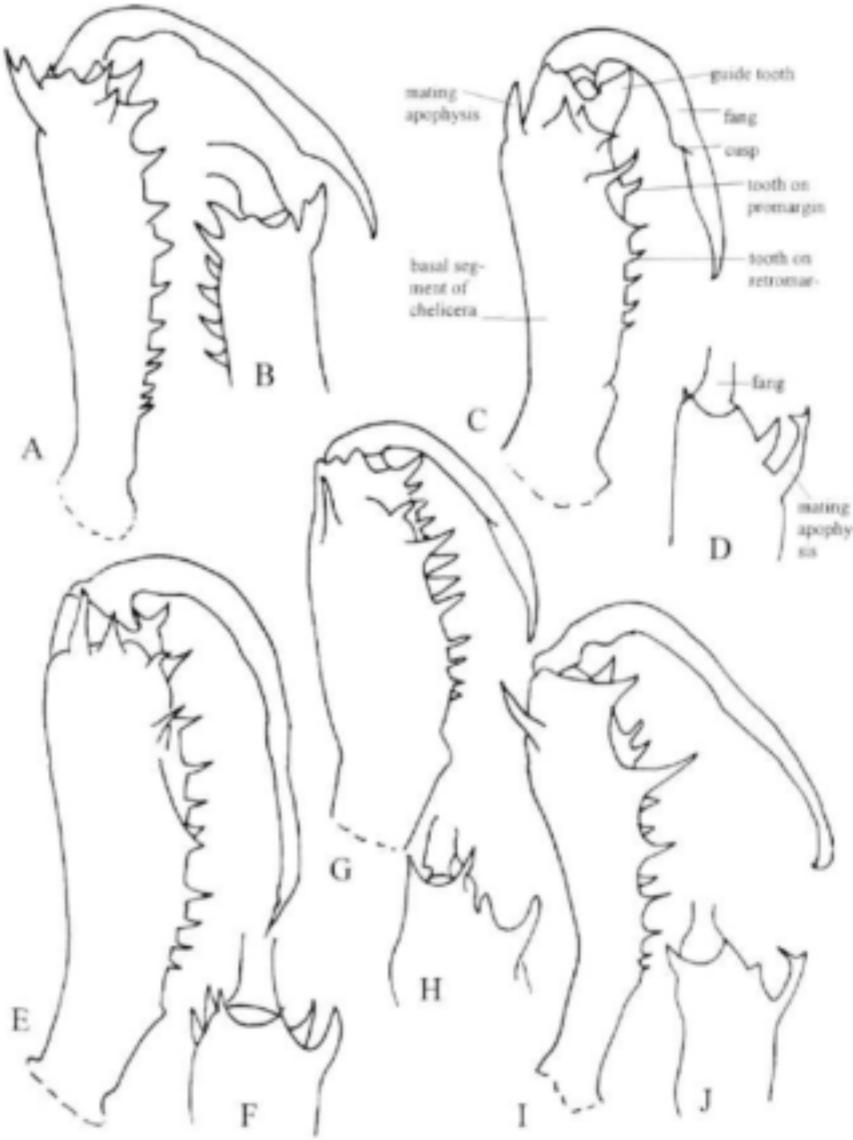

Fig. 1.6. A–J, Tetragnathidae: *Tetragnatha* spp., left chelicera of male, in dorsal view (dv) and lateral view (lv): **A**, *T. boydi* (dv); **B**, *T. boydi* (lv); **C**, *T. ceylonica* (dv); **D**, *T. ceylonica* (lv); **E**, *T. demissa* (dv); **F**, *T. demissa* (lv); **G**, *T. jaculator* (dv); **H**, *T. jaculator* (lv); **I**, *T. maxillosa* (dv); **J**, *T. maxillosa* (lv). (Drawings after Okuma & Dippenaar-Schoeman 1988).

horizontally inclined over the water surface, the spider hanging beneath with the front legs directed forwards. When disturbed, the spider frequently drops to the water surface, where it has the ability to run with great speed. Spiders in this family are nocturnal, resting on the vegetation during the day with their bodies pressed to the substrate while the front legs are stretched forwards. The webs are short-lived and taken down and digested daily. Newly hatched insects like mayflies and mosquitoes often fly straight into the webs as they emerge from the water. Tetragnathids play an important role in the control of mosquitoes in rice paddies.

A list of tetragnathid species that are associated with freshwaters has been compiled from the literature (Table 1.3). This list also includes details of distributions, diagnostic characters and sizes.

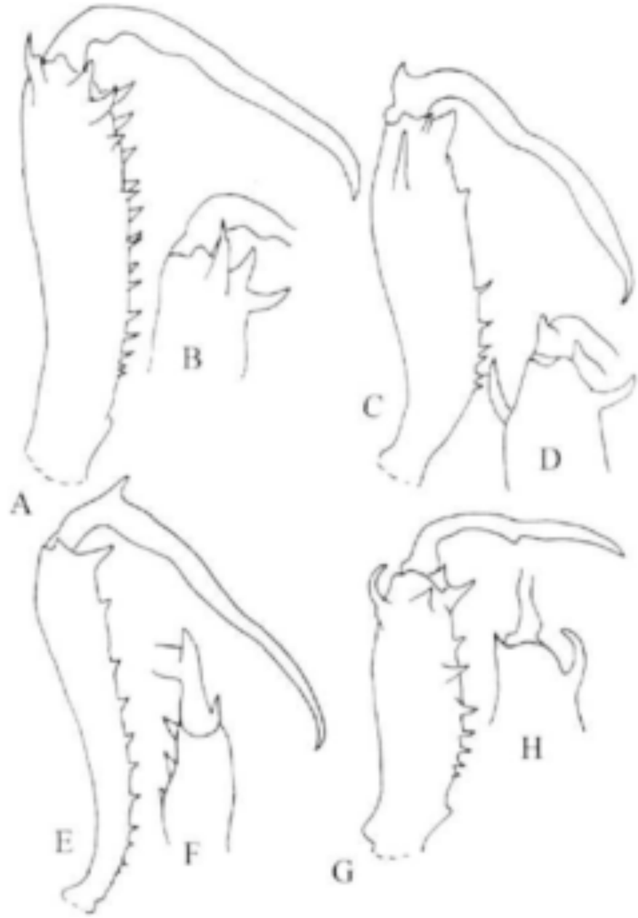

Fig. 1.7. **A–H**, Tetragnathidae: *Tetragnatha* spp., left chelicera of male in dorsal view (dv) and lateral view (lv): **A**, *T. nitens* (dv); **B**, *T. nitens* (lv); **C**, *T. subsquamata* (dv); **D**, *T. subsquamata* (lv); **E**, *T. unicornis* (dv); **F**, *T. unicornis* (lv); **G**, *T. vermiformis* (dv); **H**, *T. vermiformis* (lv).
(Drawings after Okuma & Dippenaar-Schoeman 1988).

Table 1.3. Species of *Tetragnatha* associated with fresh waters in southern Africa. Data compiled from Okuma & Dippenaar-Schoeman (1988). (Size = body length excluding legs and chelicerae)

Species & Size	Diagnostic characters	Distribution
T. boydi O. P.-Cambridge, 1898 female = 8.5–12 mm male = 8.5–10 mm	Abdomen long and narrow (Fig 1.5A), chelicerae of male as shown in Fig. 1.6A, tip of mating apophysis forked (Fig. 1.6B); fangs of female long, with cusps medially (Fig 1.7A)	South America, Nepal, Africa, South Africa: Eastern Cape, Limpopo, Mpumalanga, North West Province, KwaZulu-Natal)
T. ceylonica O.P.-Cambridge, 1869 female = 6.9–8.8 mm male = 5.6–6.6 mm	Abdomen with hump (Fig. 1.5C), more prominent in juveniles than in adults (Fig. 1.5B); chelicerae of male with uneven guide teeth (Fig. 1.6C), mating apophysis as in Fig. 1.6D; fangs of female short and smooth (Fig. 1.8C)	India, South-East Asia to New Guinea, Africa (South Africa: KwaZulu-Natal, Eastern Cape)
T. demissa L. Koch, 1871 female = 6.7–11.0 mm male = 5.9–9.0 mm	Abdomen long and narrow (Fig. 1.5D); fangs of male slightly curved with small cusps medially (Fig. 1.6E); mating apophysis curved (Fig. 1.6F); fangs of female with cusps on outer edges (Fig 1.8D)	Australia, Africa (South Africa: Gauteng, Mpumalanga, North West Province)
T. jaculator Tullgren, 1910 female = 8.1–9.0 mm male = 6.6–7.0 mm	Abdomen long and narrow (Fig. 1.5E), chelicerae of male with uneven teeth, and tips of mating apophyses slightly curved (Fig. 1.6G, H); chelicerae and fangs of female as in Fig. 1.8E	South East Asia, New Guinea, Africa (Namibia, South Africa: North West Province)
T. maxillosa Thorell, 1895 female = 9.0–9.2 mm male = 7.5–7.7 mm	Abdomen elongate (Fig. 1.5F); chelicerae and fangs of male long (Fig. 1.6I), mating apophysis with tip forked (Fig. 1.6J); fangs of female long with guide teeth well developed (Fig. 1.8F)	South East Asia, New Guinea, Africa (South Africa, KwaZulu-Natal)
T. nitens (Audouin, 1827) female = 11.1 mm male = 8.0–8.5 mm	Abdomen long oval with small hump medially (Fig. 1.5G); chelicerae and fangs of male long with well-developed guide teeth (Fig. 1.7A), mating apophysis well-developed (Fig. 1.7B); chelicerae of female strong with distinct posterior cusps (Fig. 1.9A-B)	Pantropical, South Africa (KwaZulu-Natal, Gauteng)
T. subsquamata Okuma, 1985 female = 4.9–6.5 mm male = 4.1–8.0 mm	Abdomen short, oval (Fig. 1.5H); fangs of male with fewer teeth on both margins, distinct cusps near base (Fig. 1.7C-D); chelicerae of female long and smooth (Fig. 1.9C).	East Africa, Africa (South Africa: KwaZulu-Natal, Gauteng, Mpumalanga, North West Province)
T. unicornis Tullgren, 1910 female = 9.3–11.0 mm male = 8.8–9.0 mm	Abdomen very long (Fig. 1.5I); chelicerae and fangs of male long with prominent cusps near base on outer margin (Fig. 1.7E–F); chelicerae and fangs of female as shown in Fig. 1.9D	East Africa, Africa (South Africa: Mpumalanga)
T. vermiformis Emerton, 1884 female = 7.2 mm male = 7.3–9.5 mm	Abdomen long-oval (Fig. 1.5J); chelicerae of male with uneven teeth on both margins, mating apophysis curved, fangs medially with cusp (Fig 1.7G–H); chelicera and fangs of female short (Fig. 1.9E)	India, Sri Lanka, Burma, China, Japan, USA, Africa (Botswana, Namibia, South Africa: Eastern Cape, Limpopo, Mpumalanga, KwaZulu-Natal)

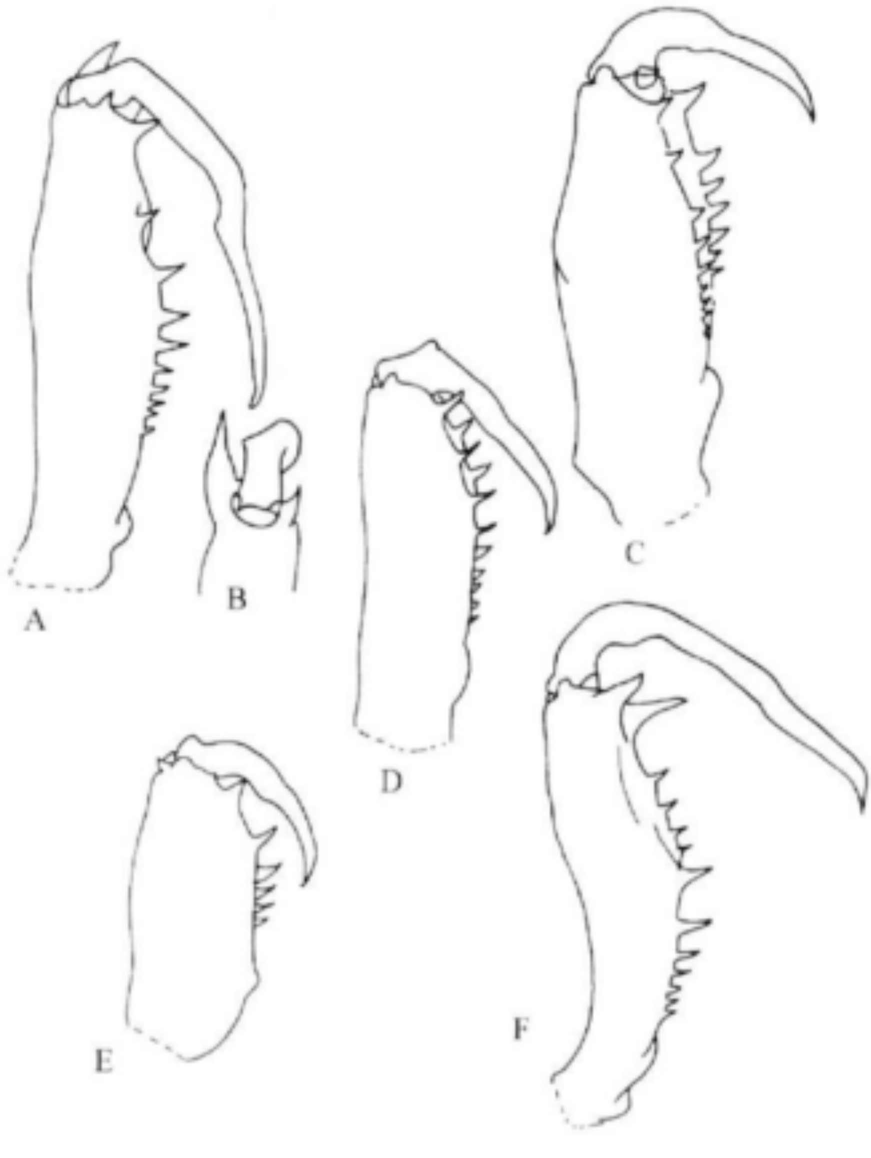

Fig. 1.8. Tetragnathidae: *Tetragnatha* spp., left chelicerae of females. **A–B**, *T. boydi*: **A**, ventral view; **B**, lateral view. **C–F**, ventral views: *T. ceylonica*; **D**, *T. demissa*; **E**, *T. jaculator*; **F**, *T. maxillosa*. (Drawings after Okuma & Dippenaar-Schoeman 1988).

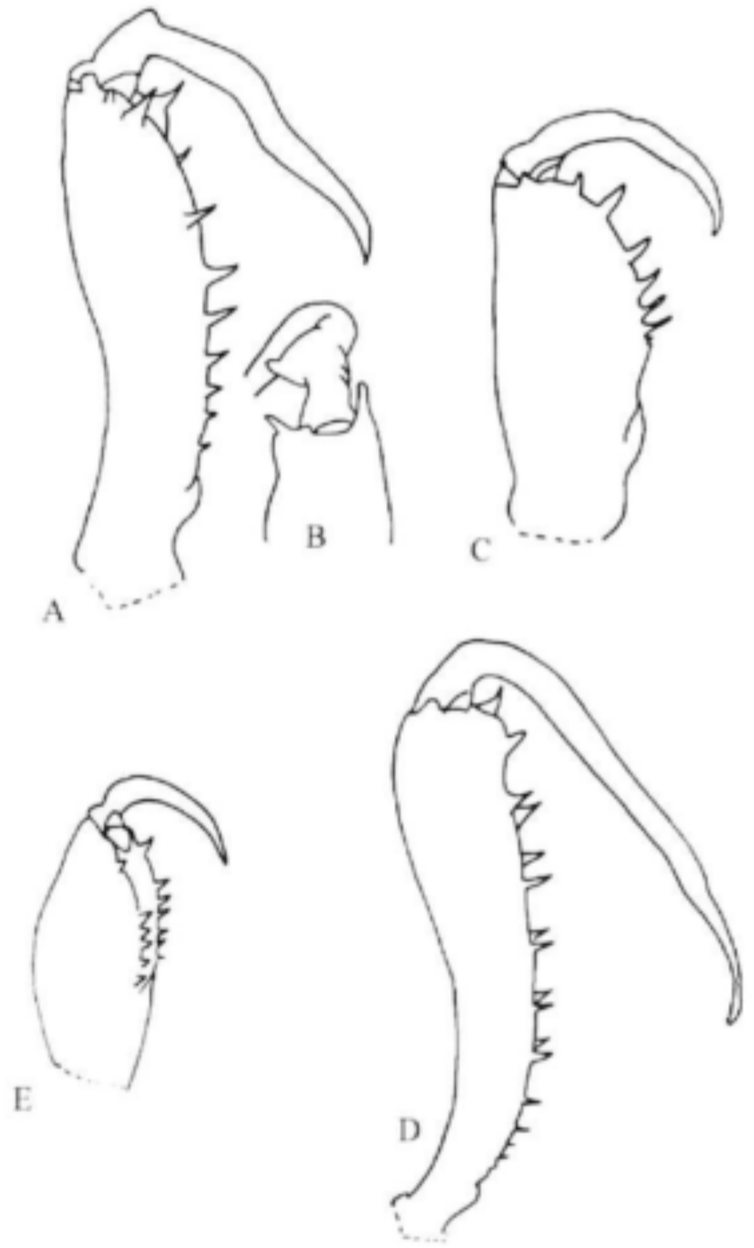

Fig. 1.9. Tetragnathidae: *Tetragnatha* spp., left chelicerae of females. **A–B**, *T. nitens*: **A**, ventral view; **B**, lateral view. **C–E**, ventral views: **C**, *T. subsquamata*; **D**, *T. unicornis*; **E**, *T. vermiformis*. (Dawings after Okuma & Dippenaar-Schoeman 1988).

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CHAPTER 2

WATER MITES

by

C.A. Jansen van Rensburg & J.A. Day*

Freshwater biologists frequently encounter tiny, brightly coloured creatures scooting busily around ponds and vleis. These are the water mites. While most mites, which form the arachnid order Acarina, are very common in terrestrial ecosystems, the suborder Trombidiformes (which includes many species of plant parasites) includes a few families that live exclusively in fresh waters. Together these forms are commonly known as the *hydracarines*. (The terms 'Hydracarina' and 'Hydrachnellae' have been used in the past as taxonomic terms but they no longer have any formal meaning.) A further family, the Halacaridae, contains several genera of marine and estuarine mites.

Members of another suborder of mites, the Cryptostigmata, normally live in soils and, because they are hard-bodied and darkish in colour, are often known as beetle mites. A few species in the genus *Hydrozetes*, in the family Eremaeidae of the division Oribatei, are found in fresh waters. Although it seems that none has yet been described from southern Africa, several apparent species are fairly commonly collected in vleis and rivers of the south-western Cape.

Distribution

Water mites are known from fresh waters throughout the world. They are common in standing waters but a few species are known to inhabit running waters; and while most species are confined to very fresh waters,

* The key to families and all of the illustrations have been copied with minor modifications from C.A. Jansen van Rensburg (1976): An identification key to the water mite families of the Ethiopian region. *Journal of the Limnological Society of Southern Africa* **2**(1): 11–20. For the sake of completeness, and to conform with the editorial conventions of the series, sections on the biology of water mites have been added by JA Day. A short note by AD Harrison deals briefly with the taxonomic relationships of water mites in southern Africa and provides useful additional references. An updated checklist of species, compiled by A.D. Harrison, can be found on the following website: http://www.ru.ac.za/aquatalogue

some occur in brackish conditions. Of the roughly 4000 species and subspecies recognized by Viets (1987), upwards of 700 species have been recorded from the Ethiopian region and of these, 160 or so are known from southern Africa. The degree of endemism does not appear to be high in that a majority of known species seems to be widespread throughout the Afrotropical region and some are also known from the Palaearctic or are cosmopolitan. Collecting has not been intensive and doubtless many more species remain to be described.

Biology

Most hydracarines are carnivorous. It appears that they, like their terrestrial counterparts, inject digestive juices into a prey animal and then suck out the digested material, rejecting the emptied skin or exoskeleton. Most hydracarines are freeliving as adults, although at least one larval stage is parasitic in aquatic invertebrates, usually insects. Members of the family Unionicolidae, however, are parasitic in freshwater mussels throughout their lives.

It appears that reproduction is always sexual. While the two sexes are sometimes very similar morphologically, in other cases sexual differences may be pronounced. Although details may differ, the process of sperm transfer usually involves the male clasping the female and using one of his third legs to transfer a spermatophore (a package containing sperm) from his genital aperture to that of the female. The female usually deposits batches of eggs onto stones, debris or vegetation. The young animal develops within the egg shell, emerging as an active larva. The larva resembles the adult except that it has three and not four pairs of legs, and no genital field (see below). In most species the young larva soon attaches to an aquatic insect and becomes ectoparasitic. After feeding for some time, the larva again becomes inactive and goes through what is almost a 'pupal' stage, before emerging as a second larva. This second, freeliving, carnivorous larva undergoes yet another 'pupal' stage before emerging as a mature adult. Some water mites that live in rivers appear to have no parasitic stage, while *Unionicola* and related genera may be parasitic on mussels for their entire lives.

More details of the biology of water mites can be found in Pennak (1989).

Collection, preservation and examination of water mites

Because of their bright colours and rapid movements, water mites are much easier to pick out when alive than when dead. Because they are so small, it is best to use a small net of mesh size <100 μm to collect them.

Most water mite taxonomists will not agree to identify specimens unless they are suitably preserved; indeed, some taxonomists insist that a specific preserving medium is used. For general purposes Pennak (1989) recommends a mixture of 5 parts by volume of glycerine, 4 parts of water and 1 part of glacial acetic acid. Pennak notes, however, that others recommend a mixture of 2 parts glycerine, 3 parts water, 2 parts glacial acetic acid and 1 part absolute alcohol (although 96% is acceptable).

Certain aspects of the specimens will have to be examined under a compound microscope and for this they will have to be mounted on slides. Pennak gives some advice on mounting, but recommends that the reader consult Mitchell & Cook (1952) for details.

External morphology

Water mites are small aquatic arthropods ranging from 0,1 to 10 mm in length. Some are bright red, blue, green or purple in life; and while in some taxa the integument is soft and pliable, in others it is heavily sclerotized.

The body (Fig. 2.1) is divided into two tagmata, the small antero-ventral **gnathosoma** and the much larger posterior **idiosoma**, to which the legs are attached. The idiosoma shows no sign of external segmentation. Its shape ranges from globular to dorso-ventrally flattened or laterally compressed, and from round to elongated. **Glandularia** (glands, each with an associated seta) are variously distributed over the surface of the idiosoma. Sometimes the idiosoma is covered by dorsal and ventral shields separated by a furrow. The dorsal surface or **dorsum** may be furnished with glandularia, sometimes associated with **platelets**, variously patterned and variously fused.

A pair of eyes is usually situated antero-laterally on the dorsum. Each eye may appear to be double. In some cases the lateral eyes are situated close together or even on a single median sclerite (Fig. 2.2F). In some genera (e.g. *Hydrachna*) a single median eye or frontal organ is situated between the lateral eyes.

The ventral surface or **venter** (Fig. 2.1) exhibits various degrees of sclerotization. The coxae of the four pairs of legs may be expanded to such an extent that they cover the major part of the venter. In general, the first and second coxae on each side are fused to form the **anterior coxal groups**, and the third and fourth coxae on each side are fused to form the **posterior coxal groups.** There are thus four coxal groups in all. Occasionally the anterior coxal groups may fuse medially (resulting in three coxal groups in all) or all four groups may be fused to form a single group. The coxae are variously ornamented and furnished with setae and glandularia.

The anterior pair of coxae are indented anteriorly to form the **gnathosomal bay**, into which the gnathosoma fits.

The **genital field** lies posterior to the coxae, very often in a posterior indentation bordered by the posterior coxae. The genital field consists of **gonopore**, **acetabula**, **genital plates** and/or **acetabular plates**. The acetabula are small cup-like structures, probably sensory in function, that may be situated in the gonopore, on acetabular plates, or free on the integument in the genital field. Acetabula may be sessile or stalked and are variable in number; they are present in all watermite superfamilies except for the Hydrovolzioidea. In most watermite families the gonopore is covered by a pair of genital plates, which may be movable and which in some families (e.g. the Hydryphantidae) carry acetabula. In some genera (e.g. *Arrenurus* and *Axonopsalbia)* the idiosoma of males carries a posterior projection, which is associated with the genital field and is distinctly demarcated from the rest of the body.

All adults (Fig. 2.1) have four pairs of legs used for walking or swimming. The three anterior pairs of legs are usually attached to a ledge formed by the lateral projection of the three anterior pairs of coxae, while the fourth pair is ventrally attached to the fourth coxae. The legs are composed of six segments distal to the coxae. The legs are numbered from

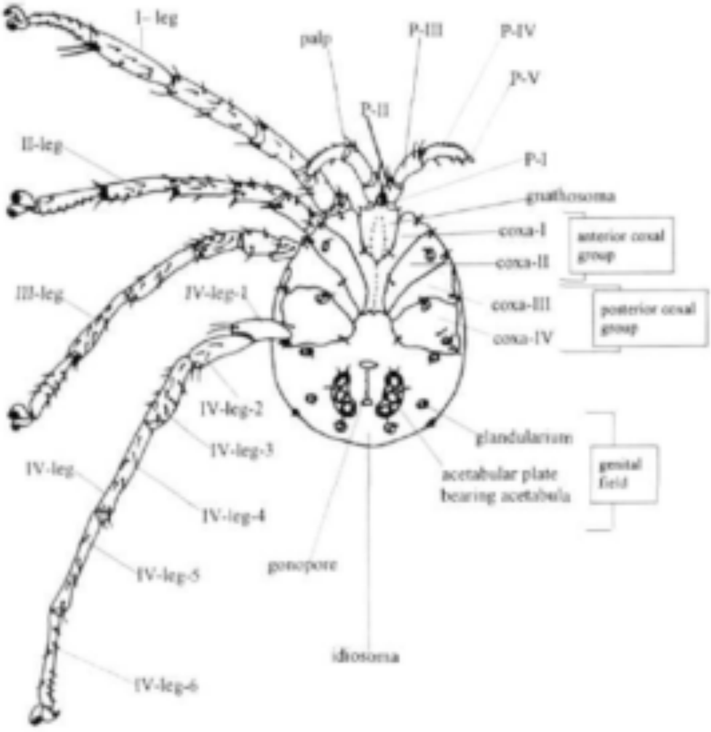

Fig. 2.1. *Atractides* sp., female in ventral view.

anterior to posterior with Roman numerals and their segments from proximal to distal with Arabic numerals. The tibia of the second leg would, for instance, be referred to as II-Leg-5. The legs are always furnished with setae, which may be long and slender in swimming forms (e.g. Fig. 2.6C), or relatively short and heavy in non-swimming forms. The last segment (the **tarsus**) usually terminates in an **ambulacrum**, which normally consists of two bifurcated claws. (In *Torrenticola* the base of the ambulacrum bears a number of vermiform projections.) Each ambulacral claw consists of a proximal flattened portion and two distal clawlets. The entire ambulacrum can be folded back into a dorsal recess in the tarsus. Sexual dimorphism of the legs occurs frequently. Usually the distal segments of the third and fourth pairs of legs of the males are modified for copulation.

The **gnathosoma** is the anterior trophic-sensory body region housing the chelicerae and bearing the palps. It consists of three fused segments: the precheliceral segment, the cheliceral segment and the palpal segment. The chelicerae are normally not visible, being housed within the gnathosoma. In all superfamilies except the Hydrachnoidea, the chelicerae are two-segmented. The **chela** is somewhat movable and may be hook-, sickle- or stylet-shaped. The **palps** are usually five-segmented, the segments being numbered from proximal to distal with Roman numerals (i.e. P-I to P-V). Chaetotaxy and the presence of chitinous projections on the palps are of taxonomic importance. Three basic types of palps can be distinguished. In **chelate** palps a dorso-distal projection of P-IV forms a chela with P-V (e.g. Figs 2.2E, 2.3D–E); in **uncate** palps P-IV is greatly expanded ventro-distally and P-V folds against it (e.g. Figs 2.9D–E); some palps are neither uncate nor chelate (e.g. Figs 2.5C, E, 2.6B, 2.8A).

Systematics

The systematics of the water mites, particularly of the Ethiopean region, have long been neglected and have not been specifically addressed since Jansen van Rensberg produced a series of papers in the 1970s. This chapter uses Cook's (1974) subordinal taxonomy, which recognizes seven superfamilies and about 44 families, 22 of which are known from the southern African region. Apart from the keys of Viets (1936, which deals mainly with European water mites), Baker & Wharton (1952, a translation of Viets's key), and Cook (1974, a comprehensive key to the world water-mite fauna), no literature is available to the non-specialist for the identification of Ethiopian specimens. A useful additional key is to be found in Pennak (1989). Although it deals with North American forms, many of the families and genera are common to both regions.

KEY TO THE ETHIOPIAN FAMILIES OF WATER MITES

1. Genital acetabula absent (Figs 2.2A– C) 2
– Genital acetabula present (arrowed in Figs 2.2D, 2.4B, 2.4F, 2.5A) 3

2. Suture lines between third and fourth coxae extending postero-laterally (arrowed in Fig. 2.2B) .... **Hydrovolziidae**
– Suture lines between third and fourth coxae extending antero-laterally (arrowed in Fig. 2.2A) .... **Pontarachnidae**

3. Palp (Fig. 2.2E) chelate, with P–I comparatively long and P–IV shorter than P–III; chelicera one-segmented and lying in the long rostrum; genital field more or less heart-shaped, with most acetabula lying anterior to the gonopore (Fig. 2.2D) .... **Hydrachnidae**
– Palp either not chelate, or if palp chelate, P–IV is longer than P–III and P–I is shorter than P–II (Figs 2.3D–E); chelicera two-segmented; genital field not as described above 4

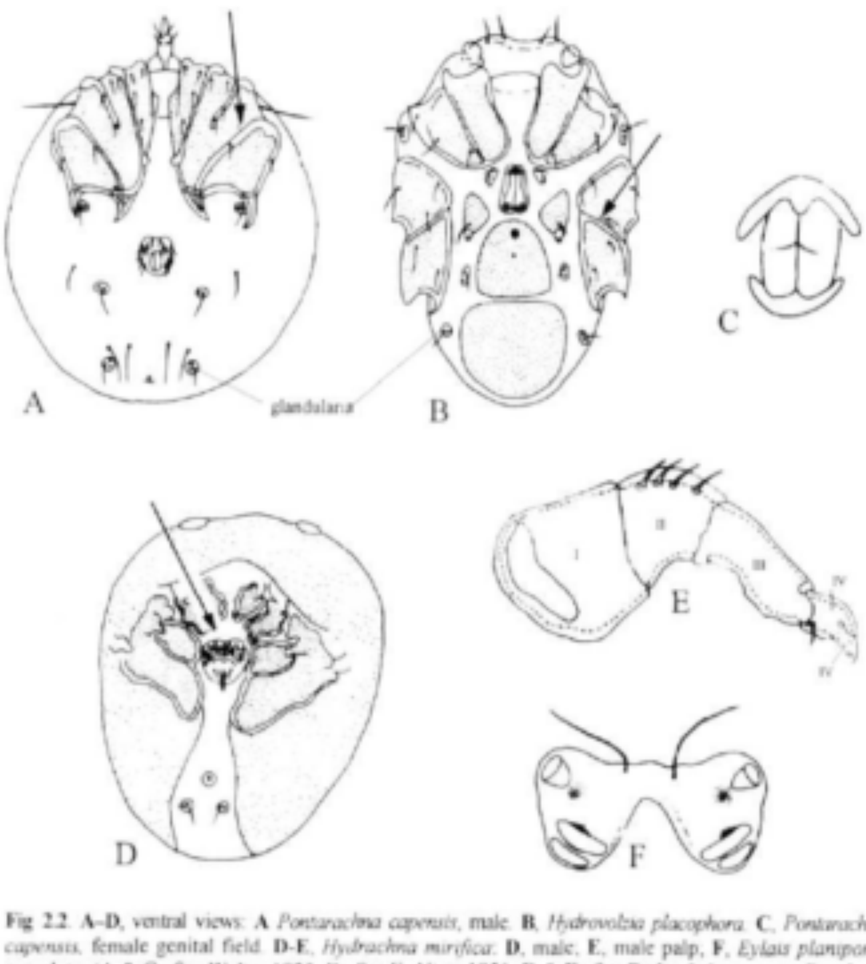

Fig 2.2. **A–D**, ventral views: **A** *Pontarachna capensis*, male. **B**, *Hydrovolzia placophora*. **C**, *Pontarachna capensis*, female genital field. **D-E**, *Hydrachna mirifica*: **D**, male; **E**, male palp, **F**, *Eylais planipons*, eye plate. (A & C after Walter 1925; B after K. Viets 1956; D & E after Bader & Jansen van Rensburg 1968; F after Walter 1924).

4. Mouth opening surrounded by a large circular membranous fringe (arrowed in Fig. 2.3A); lateral eyes, if present, incorporated into a median anterior sclerite (Fig. 2.2F); palp not chelate; genital acetabula (arrowed in Fig. 2.3C) widely scattered and not lying on or surrounded by acetabular plates……………….5
– Mouth opening either with only a very small membranous fringe or none; lateral eyes, if present, not incorporated into a median anterior sclerite; palps may or may not be chelate; genital acetabula not widely scattered, usually situated on or close to the acetabular plates ……………………………………6

5. Eye plate as wide as, or much wider than, long (Fig. 2.2F); third and fourth coxae of each side narrowly fused proximally (arrowed Fig. 2.3B)……………… ……………………………………………………………………………… **Eylaidae**
– Eye plate much longer than wide (Fig. 2.3F); third and fourth coxae of each side broadly joined (Fig. 2.3C) ……………………………………**Limnocharidae**

6. Palp distinctly chelate, with distal portion of P–IV extending far beyond insertion of P–V (Fig. 2.3E); lateral eyes of each side widely spaced with integumental lenses but no capsules ……………………………… **Hydrodromidae**
– Palp not chelate, or if palp chelate, distal portion of P–IV extends only moderately beyond insertion of P–V (Fig. 2.3D); lateral eyes variable………………… 7

7. Palp of typically chelate form (Fig. 2.3D) ………………………**Hydryphantidae**
– Palp not chelate ……………………………………………………………………8

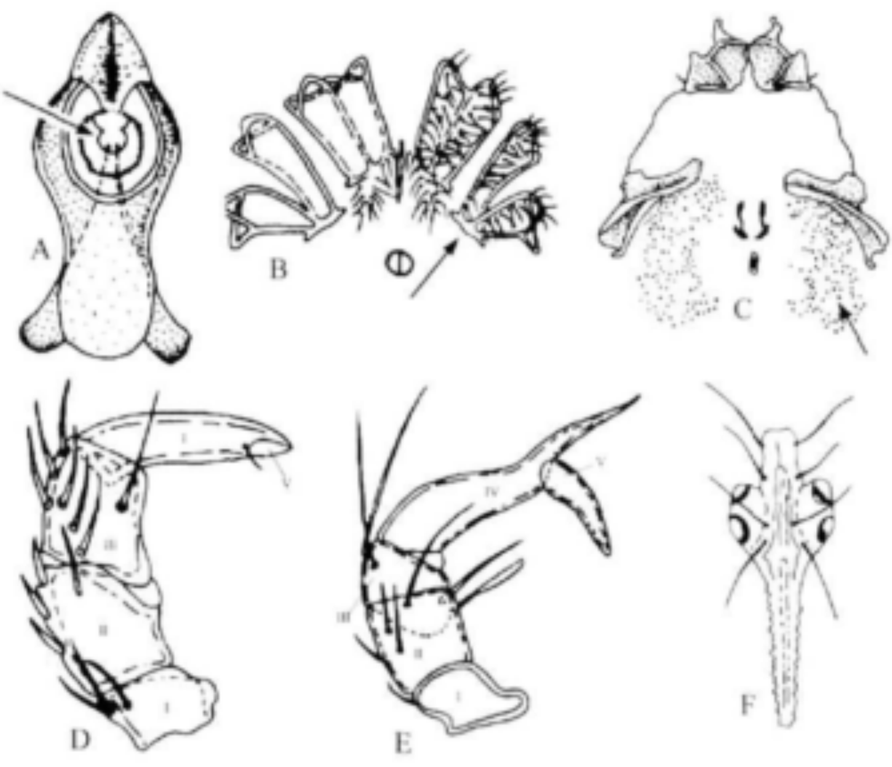

Fig. 2.3. A, *Eylais degenerata*, gnathosoma. **B**, *Eylais crenocula*, arrangement of coxae. **C**, *Limnochares crinita*, male venter. **D**, *Hydryphantes incertus*, palp. **E**, *Hydrodroma capensis*, palp. **F**, *Limnochares tenuiscutata*, eye plate. (A after Lundblad 1949; B after Cook 1966; C after Lundblad 1946; D after Bader & Jansen van Rensburg 1968; E, after Bader 1968; F after K. Viets 1914).

8. Genital acetabula located very close to each other in two parallel median rows (Figs 2.4B, 2.4.D, 2.4F & 2.5A), or (rarely) shifted laterally; acetabula usually covered by movable genital plates (arrowed in Fig. 2.4B), but these may be reduced 9
– Genital field not as described above; if movable genital plates are present, some or all acetabula lie on them 13

9. Dorsal and ventral shields present; dorsum typically covered by a large shield and two or four anterior platelets (Figs 2.4A, 2.4C); ventral shield divided by a median suture line (Fig. 2.4B) .... **Torrenticolidae**
– Not with the above combination of characters 10

10. All legs inserted far forward on body, actual insertion of fourth legs not visible in ventral or lateral views (Fig. 2.5B); ventral sides of P–II and P–III without projections or setae (Fig. 2.5C) .... **Oxidae**
– Not with the above combination of characters 11

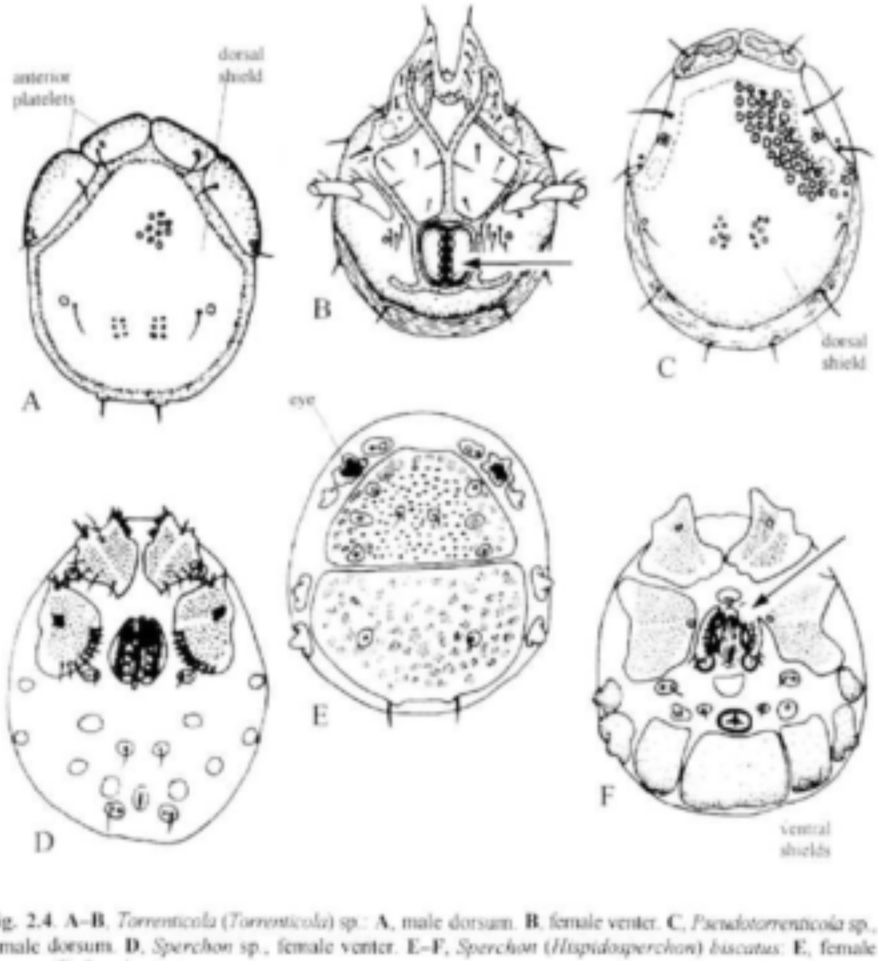

Fig. 2.4. **A–B**, *Torrenticola* (*Torrenticola*) sp.: **A**, male dorsum. **B**, female venter. **C**, *Pseudotorrenticola* sp., female dorsum. **D**, *Sperchon* sp., female venter. **E–F**, *Sperchon* (*Hispidosperchon*) *biscatus*: **E**, female dorsum; **F**, female venter.

11. Dorsal and ventral shields absent, the anterior suture lines extending anteriorly from genital field to tips of first coxae (Fig. 2.5D); suture line between second and third coxae present anteriorly and posteriorly but obliterated in middle (Fig. 2.5D); palp of a characteristic shape with a long distoventral seta on P–II (arrowed in Fig. 2.5E) and five to seven long setae on medial surface of P–III .... **Lebertiidae**
– Not with the above combination of characters 12

12. Fourth legs with well-developed claws; lateral eyes in capsules (Fig. 2.4E); a solid ventral shield never present (Figs 2.4D, 2.4F); three pairs of acetabula (Fig. 2.5A) .... **Sperchonidae**
– Fourth legs without claws (Fig. 2.5F); lateral eyes typically not in capsules; well-developed ventral shields usually present; acetabula usually three pairs (but 15–17 pairs arranged in three rows in *Sigthoria nilotica*) .... **Anisitsiellidae**

13. Dorsum and venter with numerous reticulate platelets surrounding the glandularia (Fig. 2.5G); ventral side of P–II with two or three heavy setae .... **Teratothyasidae**
– Not with above combination of characters 14

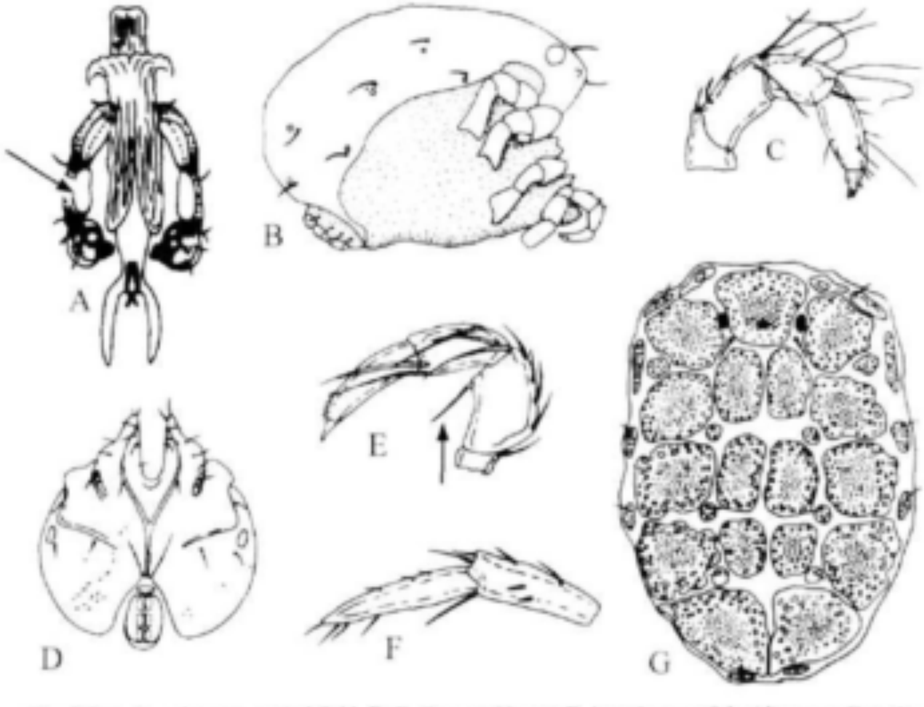

Fig. 2.5 A, *Sperchon* sp., genital field. **B–C**, *Oxus muhlmani*: **B**, lateral view of the idiosoma; **C**, male palp. **D–E**, *Lebertia capensis*. **D**, arrangement of coxae and genital field; **E**, palp. **F**, *Platymamersopsis cooki*, tip of fourth leg. **G**, *Teratothyasides* sp., dorsum. (B & C after Koenike 1895; C after Cook 1966; D & E after K. Viets 1956; F, after K.O. Viets 1970)

14. P–II with a single hair-like or peg-like seta on ventral side (arrowed in Fig. 2.6B); palps not uncate; claws usually absent from fourth leg (Fig. 2.6C); dorsal and ventral shields rarely present; genital field as in Fig. 2.6A .... **Limnesiidae**

– P–II without a single hair-like or peg-like seta on the ventral side (setae should not be confused with ventral projections) but rarely more than one seta may be present; palp may or may not be uncate; development of dorsal and ventral shields variable 15

15. I–Leg–6 much shorter than I–Leg–5; claws of first leg enlarged and able to fold dorso-proximally against a dorsal projection of I–Leg–6 to form a grasping organ (Fig. 2.6G) .... **Momoniidae**

– I–Leg–5 and I–Leg–6 various, but not as described above 16

16. Cheliceral chela serrate-denticulate on inner margin (arrowed in Fig. 2.6D); in addition to the genital acetabula, numerous acetabula lie free, even far antero-laterally, on the ventral surface (Fig. 2.6E), (these are extremely difficult to see because they are not on acetabular plates and superficially they resemble body pores) .... **Harpagopalpidae**

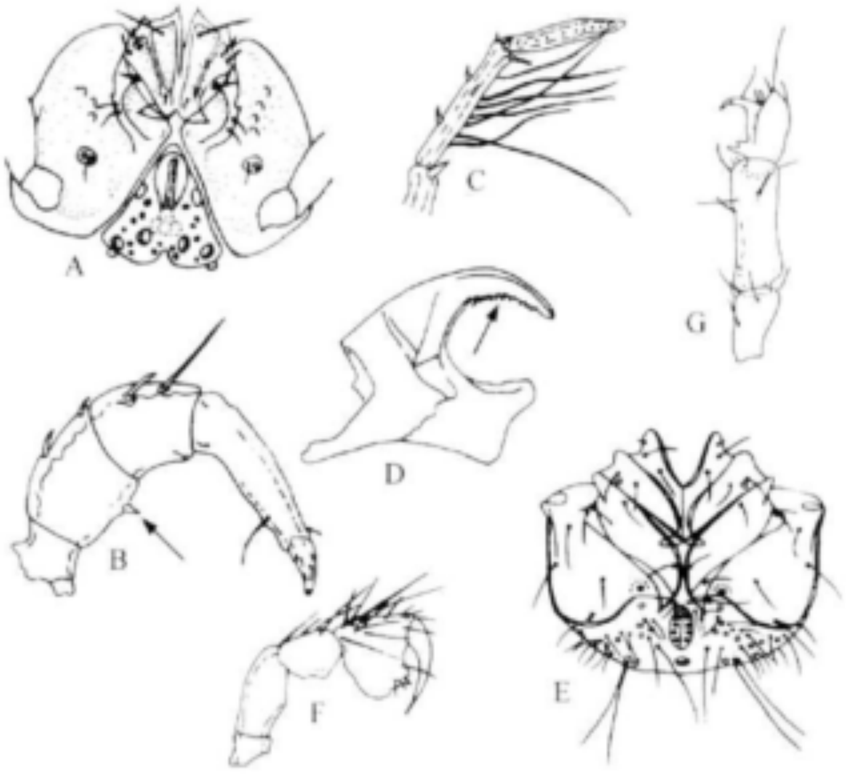

Fig. 2.6. A–C, *Limnesia* sp.: **A**, venter; **B**, palp; **C**, tip of fourth leg. **D–F**, *Harpagopalpus octoporus*: **D**, tip of chelicera; **E**, coxae and genital field; **F**, palp; **G**, *Momoniella africana*, tip of first leg of male. (D–E after K. Viets 1925; E & G after Cook 1966; F after K. Viets 1925.

– Cheliceral chela not as illustrated in Fig. 2.6D; genital acetabula usually confined either to gonopore or to acetabular plates flanking the gonopore; in a few cases acetabula are present, both in the gonopore and on the ventral surface, but are on recognizable acetabular plates and do not extend far antero-laterally 17

17. All genital acetabula confined to the genital field; well-developed condyles present at points of insertion of fourth legs (Fig. 2.7A); a pair of glandularia appear to be incorporated into the medial margins of the fourth coxae, usually close to suture line between third and fourth coxae, but sometimes more posterior than this (arrowed in Fig. 2.7A) .... **Krendowskiidae**

– Not with the above combination of characters 18

18. Seven or fewer pairs of genital acetabula present, confined to a single row on each side of the gonopore; the rows may meet each other or may almost meet each other medially (Fig. 2.7E), or may be widely separated .... **Mideopsidae**

– Not with the above combination of characters 19

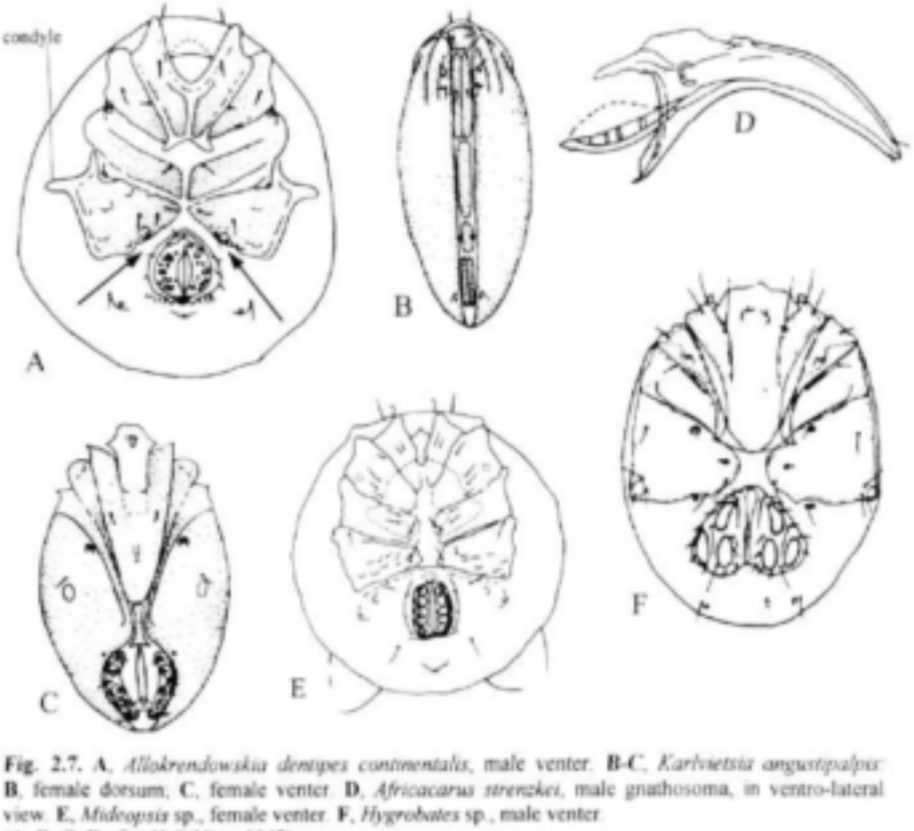

Fig. 2.7. A, *Allokrendowskia dentipes continentalis*, male venter. **B-C**, *Karlvietsia angustipalpis*: **B**, female dorsum; **C**, female venter. **D**, *Africacarus strenzkei*, male gnathosoma, in ventro-lateral view. **E**, *Mideopsis* sp., female venter. **F**, *Hygrobates* sp., male venter.
(A, B, C, D after K.O.Viets 1962)

19. Palp uncate (Figs 2.9D & E); no acetabula present in the male gonopore; genital acetabula usually extending well laterally on distinct acetabular ridges (Figs 2.9F–H) in both sexes (exception: females of *Africasia*) .... **Arrenuridae**
– Palp not uncate (e.g. Fig. 2.8A) 20

20. Body laterally compressed and noticeably higher than wide (Fig. 2.7B–C); dorsum with a narrow median strip of soft integument that may contain small sclerites (Fig. 2.7B) .... **Aturidae** (*Karlvietsia*)
– Body not laterally compressed; if body is heavily sclerotized, there is not a narrow median unsclerotized strip as illustrated in Fig 2.7B........................ 21

21. Fourth coxae bearing a pair of glandularia 22
– Fourth coxae lacking glandularia 23

22. Soft bodied (i.e. dorsal and ventral shields usually absent: Fig. 2.7F); where dorsal and ventral shields are present then (a) a turned-down seta is present at distal end of I–Leg–5 *or* (b) P–V is long, curved and pointed (Fig. 2.8A: *Hygrobatopsis*, male only) *or* (c) the gnathosoma is long and curved (Fig. 2.7D: *Africacarus*, male only) .... **Hygrobatidae**
– Dorsal and ventral shields present (Figs 2.8B–C) .... **Aturidae** (in part)

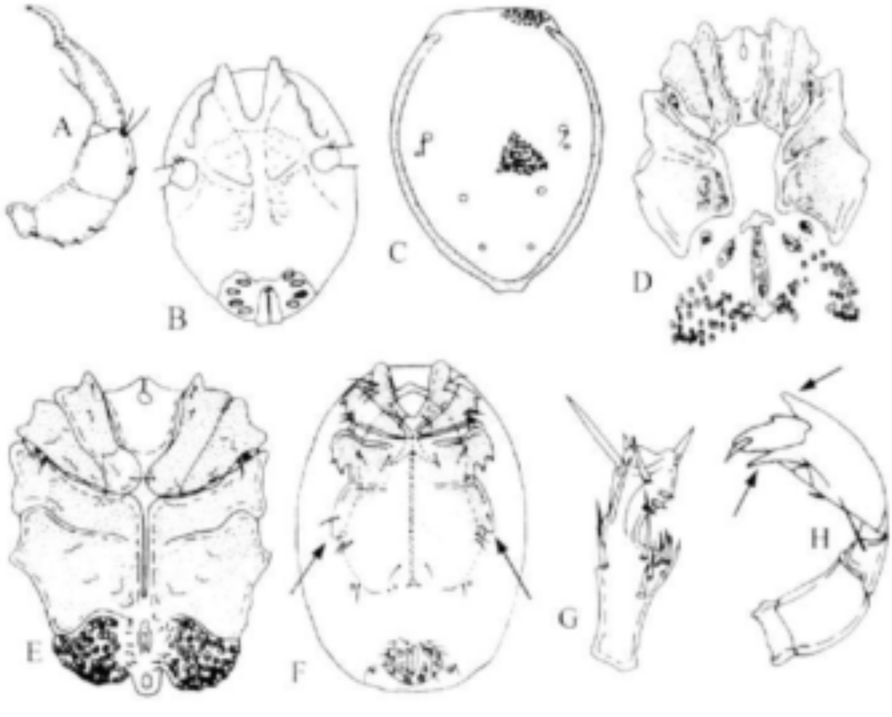

Fig. 2.8 **A**, *Hygrobatopsis levipalpis*, palp. **B-C**, *Axonopsis* sp.: **B**, female venter; **C**, female dorsum. **D–E**, *Piona damasi*: **D**, male venter; **E**, female venter. **F**, *Pollicipalpus scutatus*, venter. **G**, *Piona damasi*, male, tip of fourth leg. **H**, *Pollicipalpus projectus*, male palp. (A after Lundblad 1927; D, E & G after Lundblad 1949; F after K. Viets 1925; H after Walter 1935).

23. Soft bodied or with scattered sclerites, but without distinct dorsal and ventral shields 24
– Dorsal and ventral shields present 26

24. Genital acetabula numerous (more than 10 pairs: Figs 2.8D–E) and *either* IV–Leg–4 excavated on one side and containing numerous peg-like setae (Fig. 2.8G) *or* median surface of P–IV with a peg-like seta distally and no well-developed projections at insertion of IV-leg ....**Pionidae** (in part)
– Not with the above combination of characters 25

25. Insertion of fourth leg either with large laterally- or posteriorally-directed projection *or*, if projection extends decidedly postero-laterally (arrowed in Fig. 2.8F), then P-IV with distal projections (arrowed in Fig. 2.8H) [mites belonging to this category are known only from West Africa] ....**Unionicolidae** (in part)
– Insertion of fourth leg either with small or no associated projection *or*, if large projections are present, they are directed posteriorly or strongly postero-laterally *and* the palp is not as illustrated in Fig. 2.8H....... **Aturidae** (in part)

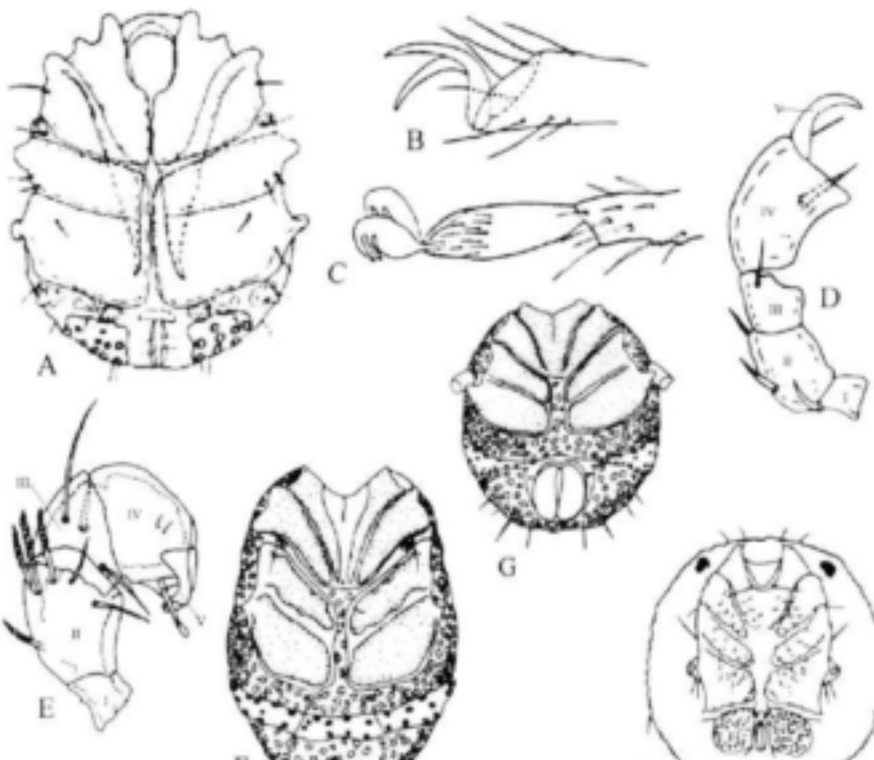

Fig. 2.9. A, *Neumania megalopsis*, female venter. **B**, *Neumania* sp., ambulacrum. **C**, *Piona* sp., tip of third leg of male. **D**, *Arrenurus forcipetiolatus*, female palp. **E–G**, *Arrenurus bowmakeri*: **E**, male palp; **F**, male venter; **G**, female venter. **H**, *Africasia radiata*, male venter. (A after K.O. Viets 1971; D after Bader & Jansen van Rensburg 1968; E–G after Jansen van Rensburg 1974; H after Cook 1966.)

26. Ambulacral claws simple (Fig. 2.9B) or with clawlets (Fig. 2.9C); posterior margins of fourth coxae more or less truncate or rounded (Fig. 2.9A); chelicerae separate or fused with each other medially; peg-like seta of P–IV, if present, variable in position, but often ventral or disto-ventral .... **Unionicolidae** (in part)
– Ambulacral claws with clawlets (Fig. 2.9C); posterior margins of fourth coxae more or less angled (Figs 2.8D–E); peg-like seta of P–IV, if present, disto-ventral or distal in position .... **Pionidae** (in part) (most species)

NOTES ON SELECTED FAMILIES

Cook (1974) recommended that the 44 water mite families existing at the time be divided into seven superfamilies. All are represented in southern Africa. The following section lists the families represented locally, together with an indication of the number of genera and species in each. The previous familial arrangement by Karl Viets, the doyen of water mite taxonomy, is also indicated.

Superfamily HYDROVOLZIOIDEA
Fig. 2.2B

Hydrovolziae *sensu* Viets

One family, the Hydrovolziidae, known from the Ethiopean region but apparently not from southern Africa.

Diagnostic characters

The integument is usually thick and lineated, often with close-fitting plates. Glandularia are typically absent, but when present the glandularial seta and the gland are situated on separate platelets. Lateral eyes are usually present except in subterranean forms. The gnathosoma terminates in a well developed hypostome (i.e. the mouth projects somewhat) and the palps are never uncate or chelate. The gonopore is covered by movable genital plates. Genital acetabula and acetabular plates are absent. The larvae are aerial (i.e. not aquatic).

Superfamily HYDRACHNOIDEA
Figs 2.2D–E

Hydrachnae *sensu* Viets

One family, the Hydrachnidae; one genus with five species known from southern Africa.

Diagnostic characters

The integument is pliable and papillate. The lateral eyes are situated on separate platelets. The gnathosoma terminates in a long curved hypostome. The chelicerae are stylet-shaped and single-segmented. The palps are chelate; P-I is the largest segment and P-III is elongate. The genital plates are immovable and the number of acetabula is variable. A protrusible ovipositor is present in females. The larvae are aquatic.

Superfamily EYLAOIDEA
Figs 2.2F, 2.3A, B, D, G

Limnocharae *sensu* Viets

Of the three families, two are known from southern Africa: the Limnocharidae (one genus, one species) and the Eylaidae (one genus, seven species).

Diagnostic characters

The integument is most frequently soft and papillate or lined. The lateral eyes are situated on a common eye plate. The mouth opening is external and surrounded by a membranous fringe. The palps are neither uncate nor chelate. Genital plates are absent; the acetabula are usually scattered and may be stalked. The larvae are aerial.

Superfamily HYDRYPHANTOIDEA
Figs 2.3E–G

Hydryphantidae *sensu* Viets

Of the six families, three are known from southern Africa: the Hydryphantidae (four genera, five species), the Hydrodromidae (two genera, three species) and the Teratothyasidae (one genus, two species).

Diagnostic characters

The integument is usually papillate, often with embedded platelets. Lateral eyes may be present. The palps may or may not be chelate. The genital acetabula, situated on the movable genital plates may vary from three pairs to many. The larvae are aquatic.

Superfamily LEBERTOIDEA
Figs 2.4, 2.5

Lebertiae *sensu* Viets

Of the seven families, five are known from southern Africa: the Sperchonidae (one genus, eight species), the Anisitsiellidae (two genera, two species), the Lebertiidae (one genus, two species), the Oxidae (two genera, three species) and the Torrenticolidae (one genus, 14 species).

Diagnostic characters

The integument may be soft or may be covered by heavily sclerotized shields. Lateral eyes may be present. The genital plates are movable and the acetabula usually lie in two parallel rows in the gonopore. The palps are never chelate or uncate. The larvae are aquatic.

Superfamily HYGROBATOIDEA
Figs 2.2A, 2.2C, 2.6A–C, 2.7H, 2.8, 2.9A–C

Pionae and Axonopsae *sensu* Viets

Of the nine families, six are known from southern Africa: the Pontarachnidae (one genus, two species), the Limnesiidae (one genus, nine species), the Hygrobatidae (eight genera, 32 species), the Unionicolidae (eight genera, 21 species), the Pionidae (one genus, four species) and the Aturidae (six genera, 11 species).

Diagnostic characters

The integument may be soft, or it may be covered with small platelets or heavily sclerotized shields. Lateral eyes may or may not be present. The palps are never chelate or uncate. Genital plates are absent and acetabula are situated on acetabular plates. (Acetabula are absent in the marine Pontarachnidae). The larvae are aquatic.

Superfamily ARRENUROIDEA
Figs 2.6D–G, 2.7A, 2.7E, 2.9D–H

Mideopsae, Krendowskiae and Arrenurae *sensu* Viets

Of the seventeen families, five are known from the Ethiopean region: the Momoniidae*, the Mideopsidae (two genera and three species), the Krendowskiidae (one genus, one species) the Harpagopalpidae* and the Arrenuridae (four genera, 17 species).

Diagnostic characters

The integument is usually porous and heavily sclerotized. Lateral eyes may be present. Movable genital plates are absent and the acetabula are situated on acetabular plates or in the gonopore. The palps are usually uncate or tending towards the uncate condition. The larvae are aquatic.

*** Not found in southern Africa**

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From the reprinted paper

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* Note that, due to difficulties experienced in obtaining full references for some publications quoted in Jansen van Rensburg (1976), in some instances use has been made of the abbreviated format as in the original publication. This does not conform to the format of the rest of this volume.

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CHAPTER 3

MOLLUSCA

by

C.C. Appleton

The Mollusca form the second largest invertebrate phylum with about 110 000 living species known to science; only the phylum Arthropoda has more species. Their rich fossil record shows the molluscs to be an ancient group of animals that was abundant in pre-Cambrian seas, more than 600 million years ago. Molluscs still occur most commonly and in greatest diversity in the sea but two of the seven classes that make up the phylum also occur in fresh and brackish water. These are the class Gastropoda (gastropods are more commonly referred to simply as snails but include the limpets and slugs) and the class Bivalvia which includes all the mussels, clams and oysters. The word 'mollusc' as used in this guide therefore refers collectively to gastropods and bivalves and the word 'snail' is used instead of 'gastropod'.

Compared to their marine relatives, freshwater molluscs are a conservative group. Their shells are relatively thin, generally some shade of brown, and have only a limited repertoire of sculptural decoration, which is best seen on juveniles. There are about 350 species of snail and 110 species of bivalve in African fresh waters but precise numbers are the subject of debate (Mandahl-Barth 1988; Brown 1994). Approximately 111 species of snail have been reported from southern Africa and Lake Malawi. This includes 101 indigenous species and ten alien species that have been introduced. Of the indigenous species, 17 (15 prosobranchs and two pulmonates) are endemic to Lake Malawi and nine others, seven species of the prosobranch genus *Tomichia* and the pulmonates *Segmentorbis planodiscus* and *Gyraulus connollyi*, are considered to be endemic to southern Africa. Three of the introduced species have become invasive while established populations of five others occur in natural or semi-natural waters (see Table 3.1). The remaining two species are known only from aquaria. A total of 26 species of bivalve is known. One, *Unio caffer*, is endemic to the subcontinent and three others, *Coelatura framesi*, *Mutela zambesiensis* and *Pisidium harrisoni*, may be endemic. There are no invasive bivalves in southern African inland waters and only one in Africa: despite its name, *Mytilopsis africana* (Dreissenidae) is native to the brack water habitats of the Caribbean islands but became established in West Africa some time before 1835.

Excluding Lake Malawi, about 12.3% of species of freshwater mollusc known from southern Africa are endemic, a very low figure when compared to the remarkable estimate of about 90% for the region's terrestrial molluscs (Herbert 1998). A checklist of species reported from southern Africa is to be found on pages 118–121.

Lake Malawi is one of the major centres of endemism for freshwater molluscs in Africa. Although its fauna is not illustrated here, it has been discussed in detail elsewhere. Crowley et al. (1964) described the hydrology and ecology of the lake and reviewed the mollusc fauna, which was identified largely on shell characters. Mandahl-Barth (1972) presented a more critical review of the fauna, taking into account anatomical details, and Brown (1980, 1994) gave updated synopses of knowledge of the snail fauna. A feature of this Lake Malawian fauna is that most of the endemic species have unusually thick shells. This may be a response to wave-induced turbulence and perhaps to predation by fish as well.

Seven species of indigenous snails are of economic importance in southern Africa because they serve as the intermediate hosts for the parasites causing bilharzia (schistosomiasis) in man and cattle, liver-fluke disease (fascioliasis) in cattle, sheep and horses, and conical-fluke disease (paramphistomiasis) in cattle and horses. Individuals of some of the larger species, notably in the family Ampullariidae, are collected by people for food. None of the bivalves are economically important, although the larger ones do make good eating.

The class Gastropoda is divided into three subclasses, two of which, the Prosobranchia and the Pulmonata, occur in fresh water. The Prosobranchia includes both large snails such as *Lanistes* and *Pila*, as well as small ones such as *Cleopatra* and *Tomichia*. The Pulmonata contains only species with small individuals such as *Lymnaea* and *Bulinus*. The Bivalvia also comprises three subclasses but only one, the Autobranchia, has representatives in fresh water. These include the large mussels such as *Unio*, *Spathopsis* and the river oyster *Etheria*, as well as the tiny fingernail or pea clam, *Pisidium*.

This guide provides a key to families of snails and bivalves living in the fresh and brackish waters of southern Africa, i.e. waters with a salinity up to about 10% that of sea water (Total Dissolved Solids of about 3–4 g/l)[1]. Several other species are characteristic of the upper reaches of estuaries

[1]In line with the use of the international Practical Salinity Scale recommended by UNESCO in 1981, all salinity measurements in the rest of this chapter are given on a dimensionless scale, i.e. without units, in which the salinity of seawater is approximately 35.

and lagoons, as well as mangrove swamps where there is a tidal influence and where salinities may rise to 15–20 or even higher for short periods. These have been included.

This key is followed by illustrations and notes on the species. One family, the Ancylidae, and several genera of others, notably *Tomichia* (Pomatiopsidae), *Bulinus* (Planorbidae) and *Pisidium* (Sphaeriidae), are not dealt with fully because they either need taxonomic revision or they contain species that are difficult to separate without specialist knowledge. Readers wanting more detailed information on freshwater molluscs in both a regional and an Africa-wide context should consult Brown (1980, 1994) and Mandahl-Barth (1988) for snails and bivalves respectively.

GENERAL BIOLOGY

Molluscs are soft-bodied, unsegmented animals that normally live inside a shell. Freshwater snails (Figure 3.1A–C) have a large, ventral muscular **foot** and a well developed head bearing a single pair of **tentacles**. Eyes are present at the bases of the tentacles in both the Prosobranchia and the freshwater Pulmonata (Basommatophora) but they are simple in structure and can probably do little more than distinguish light from dark. Terrestrial pulmonates (Stylommatophora), represented in this guide by the family Succineidae, have two pairs of tentacles with their eyes at the tips of the posterior pair. There is no recognizable head in the bivalves and the foot is relatively small since they are sedentary animals, being immobile for most of their lives, either buried in sand or mud with only their posterior ends protruding or attached to submerged substrata such as rocks.

All freshwater species of both classes have an external **shell**: a single, usually coiled, unit in gastropods, or two valves joined by a ligament and hinge in bivalves. Snail shells may be either **dextral**, if the shell's aperture is on the observer's right when the spire points upwards, or **sinistral**, when the aperture is on the observer's left. The direction of coiling is almost always constant for each family; an exception is the Ampullariidae, which contains both dextral and sinistral species. In the family Ancylidae, shells have lost their coiled form and have become cap-shaped. The two valves comprising the shell of bivalves are generally mirror images of each other and are called **equivalves**. The freshwater oyster (*Etheria elliptica)* is an **inequivalve,** however, since its lower valve is cemented to the substratum and has a different shape from the upper one.

The molluscan shell is made up of several layers: an outer **periostracum** composed of a protein matrix called **conchiolin** and several mineralised layers, mostly of calcium carbonate, on the inside. The structure and strength of the shell varies according to the chemistry, especially

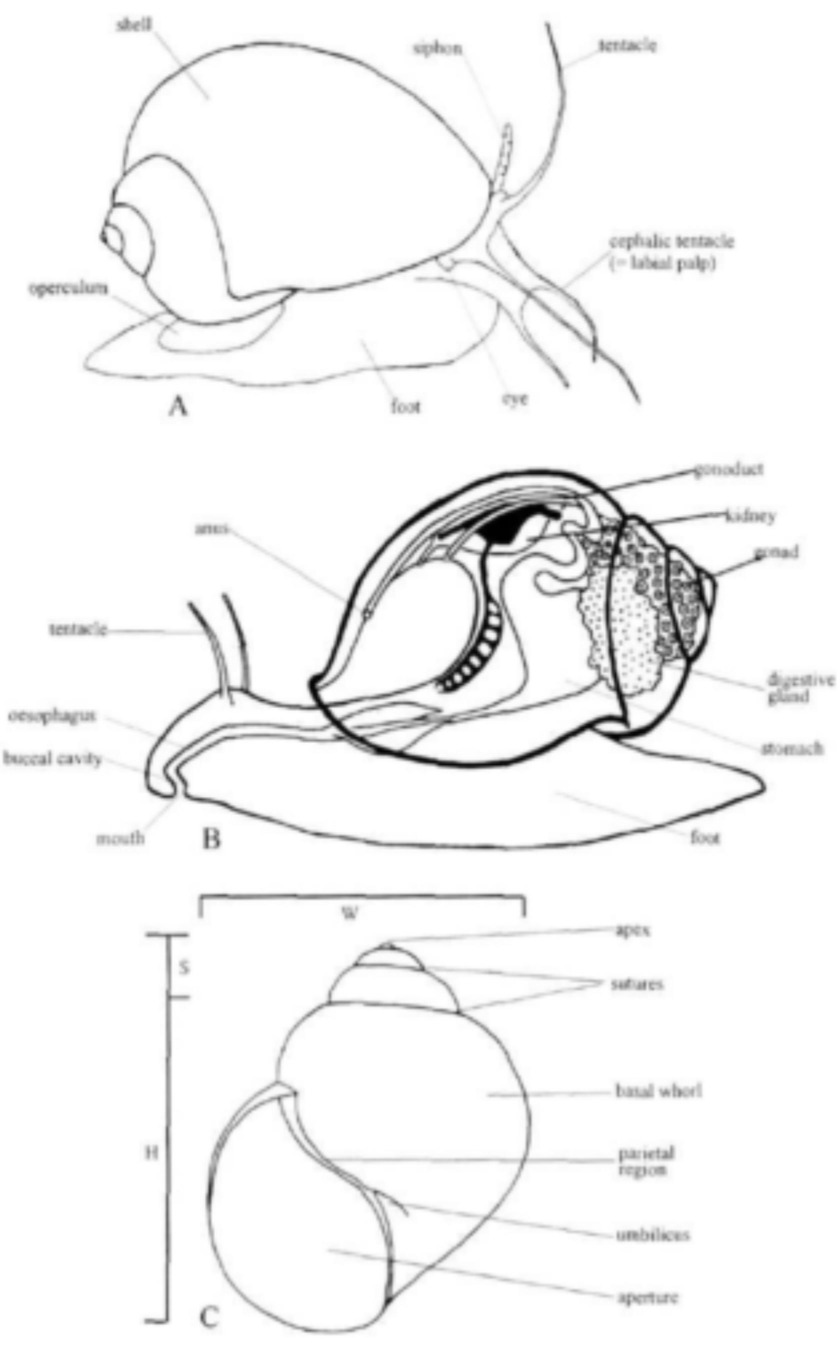

Fig. 3.1. Morphological and anatomical features of prosobranch and pulmonate snails. **A**, a prosobranch snail (*Pomacea* sp.): note the two pairs of tentacles with the eyes at the base of the upper pair, the branchial siphon on the animal's left hand side, and the operculum attached dorsally to the posterior end of the foot. **B**, a pulmonate snail (*Bulinus africanus*) showing internal anatomy and generalized shell shape: note the single pair of tentacles and the absence of an operculum. **C**, morphological features of a gastropod shell (*Lanistes ovum*): H = shell height (sometimes referred to as 'shell length' in gastropods). S = spire height, W = maximum shell width.

the pH and hardness, of the water in which the mollusc lives. As noted above for the molluscs of Lake Malawi, other factors may also influence shell thickness.

The shell's main function is to protect the animal's delicate **visceral hump**, which contains the visceral organs such as the heart, kidney, digestive gland and gonad (see Fig. 3.1B), and provides a space into which the foot can retract when necessary. In the Prosobranchia, the shell's aperture can be closed by an **operculum** (Fig. 3.2A–B) which is attached to the posterior end of the foot. Like the shell, the operculum may be made of calcium carbonate, but more often it is made of conchiolin, in which case it is described as being **corneous** or **horny**.

The shell is formed by the membranous **mantle,** which also covers the visceral hump. Anteriorly within the hump the mantle encloses a space, the mantle cavity, which in the Prosobranchia contains a single gill. Many prosobranchs, for example the Ampullariidae, can also breathe air but gills remain their main organs of respiration. In the subclass Pulmonata (air-breathing snails) the gill has been lost and respiration takes place via the roof of the mantle cavity, which has become richly supplied with blood vessels and is, in effect, a lung. Pulmonates can also breathe through their skins by removing oxygen dissolved in the water. This may be the main respiratory mechanism for some species.

As a snail shell grows, it coils around a central axis called the **columella** the youngest part of which is visible ventrally and is known as the **umbilicus**. The umbilicus is said to be open in species which have a hollow columella, and closed in those in which it is solid. Each successive coil around the columella is called a whorl and all the whorls except the

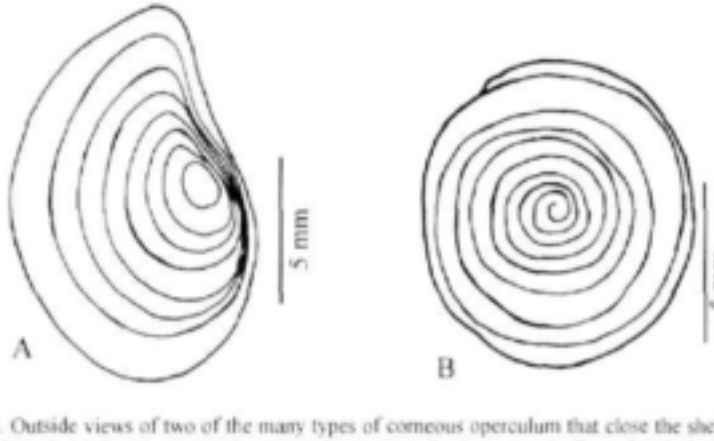

Fig. 3.2. Outside views of two of the many types of corneous operculum that close the shell apertures of prosobranch snails: **A**, concentric, sinistral type (e.g. *Lanistes ovum*); **B**, multispiral, dextral type (e.g. *Terebralia palustris*).

last form the **spire**. The last whorl is the largest and is the **basal** or **body whorl**. The tip of the spire is the **apex**. Periods of growth are marked by fine radial lines or **striae** on the shell. Longer periods of shell growth in, for example, prosobranchs, may be marked by thicker radial lines called **varices**. A bivalve shell grows in a similar way, each period of growth being marked by striae radiating from the **umbone**. Certain standard conventions that describe aspects of animals, such as 'lateral', 'dorsal' and 'ventral', are inappropriate for gastropod molluscs, and use is made of terms such as 'apical view', 'underside view' and 'apertural view' (see glossary).

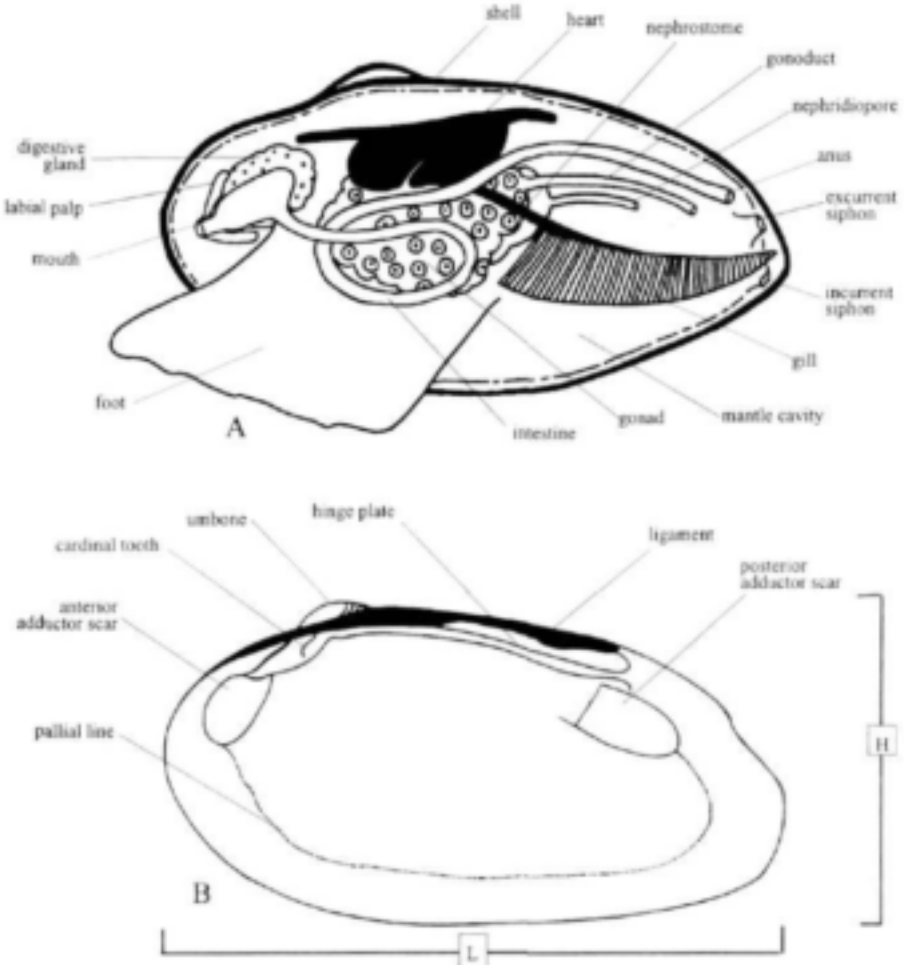

Fig. 3.3. Morphological and anatomical features of a bivalve mollusc (*Unio caffer*). **A**, internal anatomy; **B**, shell. L = shell (valve) length; H = maximum shell (valve) height. Maximum width (not shown) can be measured when both valves are held together in the closed position.

In the bivalves (Figs 3.3A–B) the body is elongate and laterally compressed and its visceral organs are contained within a **mantle,** which has two enlarged lobes enclosing a spacious **mantle cavity** running the length of the shell. This cavity contains elongate, paired gills and the animals breathe through these as well as through the extensive **mantle lobes** that line each shell valve. These lobes secrete the matching shell valves, which are hinged dorsally by a ligament. The valves, which close when the powerful **adductor muscles** contract, are usually equipped with hinge teeth to lock them in the closed position. Like the mantle lobes, the gills are also enlarged and serve not only for respiration but also for filtering food from water drawn into the mantle cavity from the surrounding water. In the larger mussels, brood sacs or **marsupia** develop on the gills and serve to incubate the embryos before they are expelled into the water.

In terms of gross anatomy, two organ systems occupy most of the internal body space in molluscs, the reproductive and the digestive systems. The detailed structure of the **radula** in the mouth cavity and certain features of the reproductive system, especially the male section in hermaphrodites (see under 'Reproduction') are useful for identifying freshwater snails. In freshwater bivalves, the number and arrangement of the hinge teeth are important, as is the structure of the gills, especially the way their filaments are interconnected.

Freshwater molluscs differ widely in life-span. Amongst the snails, prosobranchs may live for one or two years whereas pulmonates may do so for only six months to a year. The bivalve *Corbicula* is thought to have a life-span of six to eight years and the unionacean mussels, which are much larger, may reach ages of up to 12 years (Kenmuir 1980).

Reproduction

Gastropoda

Prosobranch snails are generally either male or female, although individuals of some species change sex as they grow. They vary in their reproductive style and may be oviparous (e.g. families Ampullariidae and Pomatiopsidae), viviparous (e.g. Viviparidae) or ovoviparous (e.g. Thiaridae). Members of some genera in the Thiaridae are parthenogenetic, functional adults developing from unfertilized eggs.

Oviparous species lay their eggs in clusters of, for example, hemispherical capsules on the under surfaces of leaves (e.g. Bithynidae), or spherical, hard-shelled (calcareous) eggs above the water level (see Ampullariidae). Viviparous and ovoviparous species give birth to live young, which resemble their parents. These young develop in a part of the uterus, which is expanded to form a brood pouch.

Pulmonates are oviparous hermaphrodites, with male and female sex organs occurring in the same individual and usually in the same organ. Snails of the family Planorbidae, which include the intermediate hosts of several important trematode flukes, provide good examples of hermaphrodite reproductive anatomy. As in all hermaphrodites, the system consists of three main parts, a hermaphroditic or common section, a female section and a male section. A detailed description of this type of reproductive system in *Biomphalaria* and *Bulinus* is given by Mandahl-Barth (1958). It is important to note that certain of its structures favour cross-fertilization by preventing self fertilization while, at the same time, storing a supply of donor (exogenous) sperm from several donors for several weeks at a time.

The eggs of pulmonate snails are laid in gelatinous capsules, which adhere to submerged surfaces such as stones and leaves. Individual eggs are surrounded either by a single (internal) membrane or by this internal membrane and a second (external) membrane as well. The capsule itself is covered by one or two gelatinous envelopes. Note that the details of the protective membranes around eggs and the gelatinous envelopes around whole capsules can only be seen through a microscope.

Planorbid snails lay clutches of up to 20 eggs in a spiral inside a flat, yellowish capsule (Fig. 3.4A–B). Limpets of the family Ancylidae also lay clutches of up to 15 eggs in a spiral within a capsule, but this has a second protective layer around it (Fig. 3.4C). Lymnaeid snails lay large, colourless, sausage-shaped egg masses up to about 20 mm long with up to 30 eggs (Fig. 3.4D) while those of the Physidae are larger still, although not as long, and contain up to 40 eggs. Depending on the water temperature, pulmonate eggs take between one and four weeks to hatch. Bondesen (1950) provided a detailed account of the egg masses of the families of strictly freshwater pulmonates (Lymnaeidae, Ancylidae, Planorbidae and Physidae) and a modified version of his key for the four families found in South Africa is given below.

KEY TO THE EGG CAPSULES OF THE FOUR COMMON FRESH WATER PULMONATE FAMILIES FOUND IN SOUTHERN AFRICA.

1. Capsule soft and jelly-like, markedly convex, clear and transparent, elongate-oval to cylindrical, straight or more-or-less curved; tail free; individual eggs with internal and external membranes..2
– Capsule firm, only slightly convex, often yellowish in colour, spiral in form; tail usually attached to the substratum, rarely free; individual eggs with no external membrane... 3

2. Tail open-ended, usually well developed; capsule turns to the left (i.e. anti-clockwise); external membrane around egg thin-walled, made of fine, hardly visible lamellae.. Lymnaeidae
– Tail closed, usually poorly developed; capsule turns to the right (i.e. clockwise); external membrane around egg well developed with both coarse and fine lamellae...Physidae

4. Capsule small, up to about 2 mm in diameter, with a second envelope ....Ancylidae
– Capsule larger, up to 4–6 mm in diameter, without a second envelope ....Planorbidae

Hermaphroditism is advantageous in habitats which are inherently unstable and may dry out or be subject to floods. Under conditions such as these, encounters between males and females cannot be relied on and repopulation or recolonization may depend on reproduction by a few survivors or colonists. In such situations being a hermaphrodite allows copulation between any two individuals of the same species at every meeting. In this way cross-fertilization is encouraged and genetic diversity preserved. Aphally, or the lack of a functional copulatory organ, is known to occur in some populations of *Ferrissia* and *Bulinus*. In these cases, self-fertilization must occur.

In all these species, fertilization of eggs is internal and takes place after copulation. In contrast to the situation in many marine snails, there are no free-living larval stages (except in the Ellobiidae, members of which are estuarine) and embryos generally undergo direct development inside eggs. They hatch as miniature adults. Some genera, e.g. *Pila* and *Pomacea* of the family Ampullariidae, lay hard-shelled, pink or white eggs about 3 mm in diameter. Clusters of eggs are laid at night on firm surfaces such as emergent vegetation 100–115 mm above the water. After a minimum of 15 days, the hatchlings break out and drop into the water. Members of the genera *Lanistes* and *Marisa* lay eggs without shells in gelatinous clusters under the water. Other prosobranchs, such as *Bellamya* (Viviparidae) and *Melanoides* (Thiaridae), are viviparous: embryonic development occurs

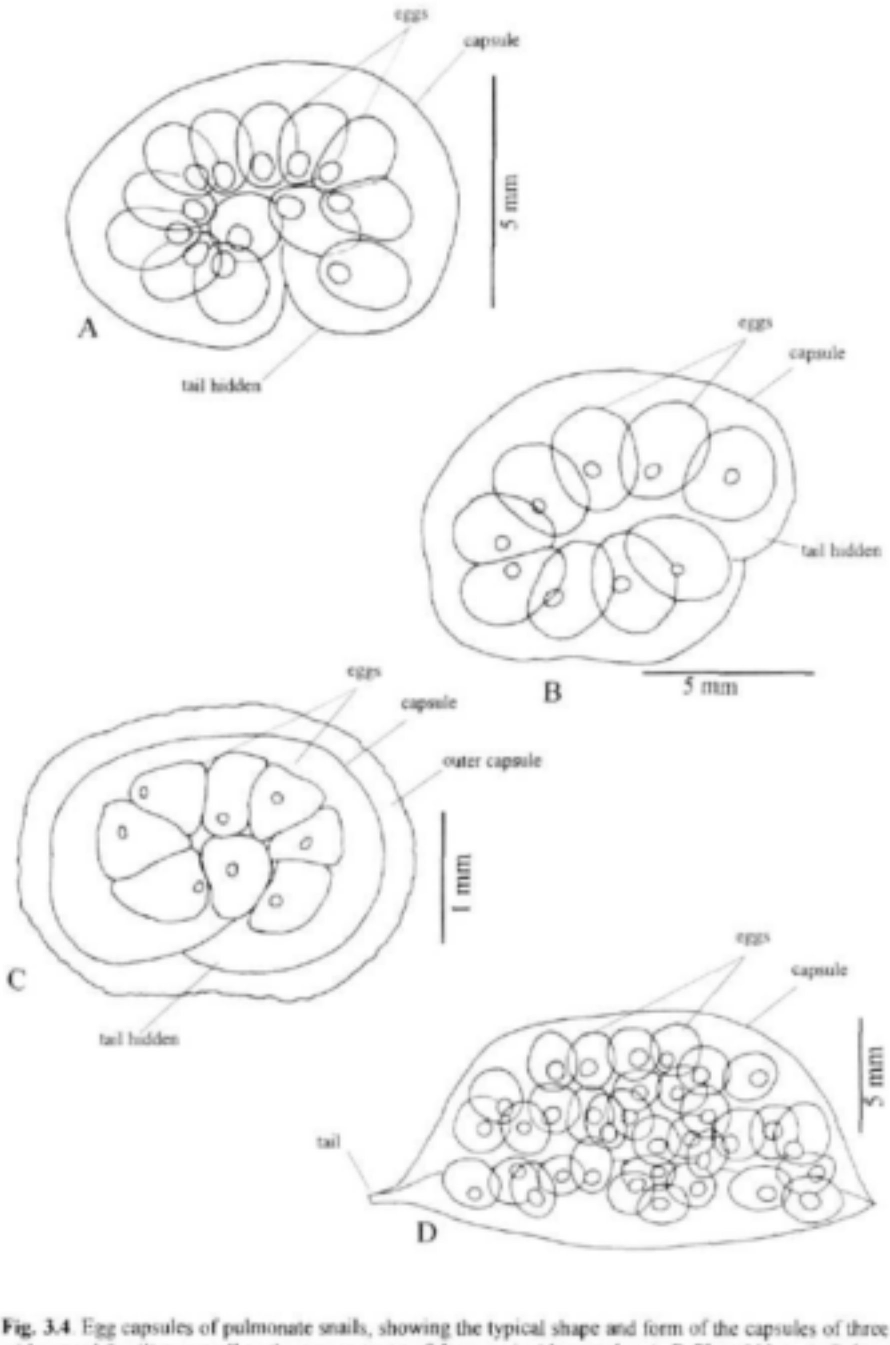

Fig. 3.4. Egg capsules of pulmonate snails, showing the typical shape and form of the capsules of three widespread families as well as the arrangement of the eggs inside capsules. **A–B**, Planorbidae: **A**, *Bulinus africanus*; **B**, *B. tropicus*. **C**, Ancylidae: *Burnupia* sp. **D**, Lymnaeidae: *Lymnaea natalensis*.

within a brood pouch situated internally above the buccal mass of the female, and the young are born alive. In these families, males are often rare and populations may be comprised largely or exclusively of females, which reproduce by parthenogenesis. Where male specimens of *Melanoides tuberculata* have been found, some have been sterile, but others have produced viable sperm indicating that sexual reproduction does occur under certain circumstances (Hodgson & Heller, 1990).

Bivalves

The small mussels belonging to the Sphaeriidae and Corbiculidae are hermaphroditic and viviparous whereas the larger unionacean mussels of the Unionidae and Mutelidae may either be separate-sexed or hermaphroditic and viviparous. A pair of gonads is situated in the dorsal part of the foot with ducts discharging ripe gametes into either side of the mantle cavity from where they are discharged into the water.

The Unionidae and Mutelidae have evolved an extraordinary reproductive process in which sperm is discharged into the surrounding water but the egg cells attach themselves inside special brood chambers or marsupia on the gills inside the mantle cavity. These egg cells are then fertilized by foreign sperm drawn into the cavity from outside with the inhalent feeding current, and develop into glochidia (Unionidae) or haustorial larvae (Mutelidae). Some species use all four gill plates (demibranchs) for brooding while others use only two.

When fully developed, these glochidial and haustorial larvae have a tiny (<0.5 mm) bivalved shell and are equipped with various devices whereby they attach themselves as parasites to the fins, skin or sometimes the gill filaments of fish. Amongst the southern African Unionidae, the glochidia of *Unio caffer* have a hook on each shell valve for attachment to the host fish (Heard & Vail 1976), while those of *Coelatura mossambicensis* and other species of the genus are D-shaped and hookless but have instead a long thread, which becomes entangled in the fish's gill filaments (Kenmuir 1980). The larvae of the Mutelidae look rather different and are known as haustorial larvae. Those of *Spathopsis wahlbergi* have hooks as well as two retractile, ciliated lobes, which presumably help them swim through the water. The larvae of *Mutela zambesiensis* also have hooks and ciliated lobes as well as a thread-like tentacle 10–15 mm long (50–70 times longer than the larva's body). For a detailed account of the life-cycle of *Mutela*, see Fryer (1959, 1961).

When expelled from the parent mussel into the water via the exhalent current, the larvae are not only covered with mucus, and therefore sticky, but they also mimic the food of fish (e.g. worms). They will only survive if they make contact with and attach to a host fish on which they will eventually become physiologically dependent. If successful, they will live as ectoparasites on their host fish for a period ranging from a week to several months before dropping off onto the substratum and becoming free-living adults. If unsuccessful, they will die. Although these larvae are obligatory parasites, they are not generally thought to be host-specific. Some species, such as *C. mossambicensis* and *Spathopsis wahlbergi*, however, appear to be more host-specific than, for example, *M. zambeziensis*, which will develop on a variety of fish species, although mostly on cichlids (bream) (Kenmuir 1980).

The parasitic stages of unionid and mutelid bivalves often harm their hosts. Larvae of *C. mossambicensis* and *S. wahlbergi* attach by pinching pieces of host tissue between their shell valves and then becoming encysted within the epidermis of the fish's skin, fins or gill filaments. This can interrupt blood flow to parts of the affected tissues. The **haustorial larvae** of *M. zambesiensis* do not become encysted but rather attach themselves to the host fish by means of special stalks (haustoria). Heavy infestations of any of these larvae can kill a host fish. Nevertheless, these fish play a crucial role in the life-cycles of these bivalves. Not only do they provide the developing larvae with nourishment but they are also vital to the dispersal of the otherwise sedentary young mussels to suitable new habitats. Without their host fish, populations of these mussels will disappear.

Fecundity in freshwater molluscs is generally high. In temperate regions, they may be expected to show a seasonal breeding pattern, chiefly during spring and early summer, followed perhaps by a period of hibernation in winter. In areas with cold winters, the prosobranch *Melanoides tuberculata* may hibernate in sand for 2 to 32 months. In tropical and subtropical areas breeding may continue throughout the year. Females of species such as *Pomacea lineata* may produce up to 100 eggs during their lifetimes, while parthenogenetic species such as *Melanoides tuberculata* breed continuously for several months and may have up to 75 developing embryos in the brood pouch at any one time. Female *Bellamya capillata* may brood up to 61 embryos at a time but brood size depends on the female's age and also on population density (Joubert 1977). Pulmonate snails such as *Bulinus globosus* may produce up to 1700 eggs each during their lives, at an average of 10–14 eggs per day. The mussel *C. mossambicensis* will have many thousands of eggs in its brood chambers at any time (from 10 000 in a small specimen to 26 000 in a large one) and it may breed annually for several years (Kenmuir 1980). Spatfall by the small brackish water species *Brachidontes virgiliae* on the leaves of *Potamogeton* in Swartvlei was reported to exceed 2.5 million/m^2 in summer (Bernard et al. 1988). In most of these cases of extremely high fecundity, mortality amongst juveniles is likely to be severe.

Feeding

All snails feed by means of a radula — a remarkable structure, which is peculiar to molluscs and found in all classes except the Bivalvia. It is well developed in the gastropods and consists of a 'ribbon' on which are attached a myriad rows of tiny, recurved **teeth** each bearing a number of **cusps**. This ribbon lies over a muscular **odontophore** that projects into the **buccal cavity** or mouth of the snail and moves forwards and backwards so that the teeth scrape up food from the substratum over which the animal is travelling. There are usually several types of teeth in each row on the radula: a single central tooth with lateral and marginal teeth on either side (Fig. 3.5A–D). These different types of teeth have different functions in the feeding process. The central and lateral teeth serve to rasp or comb the periphyton and detritus off submerged surfaces while the marginal teeth act as rakes, guiding the loosened particles towards the radula's midline and upwards into the oesophagus.

Analyses of stomach contents have shown that most groups of freshwater snails are generalists, feeding on the periphyton growing on submerged surfaces. Their diets therefore consist largely of detritus, which may be expected to be rich in bacteria. In addition to detritus, pulmonates (e.g. *Lymnaea*, *Biomphalaria*) and the smaller prosobranchs (e.g. *Cleopatra*, *Melanoides*) have been reported grazing on microscopic organisms such as epiphytic chlorophyte algae, diatoms, decaying macrophyte tissue, and, more rarely, on fungi, blue-green algae, fresh macrophyte tissue or animal remains as well. The relative proportions of these foods will vary from one habitat to another. Larger prosobranchs such as *Lanistes* feed mostly on dead macrophyte tissue, diatoms and detritus. The introduced *Marisa cornuarietis* is one of the few species that feeds indiscriminately on living plant tissue and this is why it has earned a reputation as a most undesirable immigrant.

The collection of food does not seem to be selective except that the size of the snail's mouth and the gaps between the cusps of individual teeth may limit the size of particles that can be eaten. Studies of the trails left behind by grazing snails show that these molluscs remove all or almost all of the periphyton as they feed (Fig. 3.6). The number of these teeth in each row of the radula, and the number of cusps they have, are of taxonomic importance since they often differ between species.

With the exception of the brackish water mussel, *Brachidontes virgiliae*, and the river oyster, *Etheria elliptica*, which live attached to

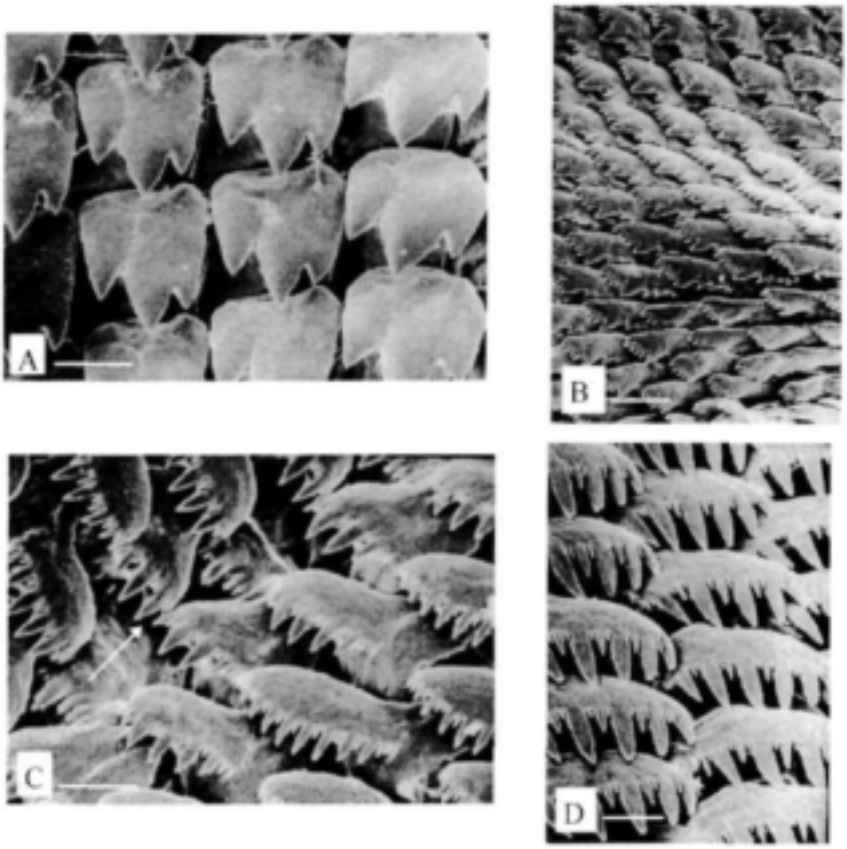

Fig. 3.5. Scanning Electron micrographs of the radula teeth of *Lymnaea natalensis* and *Physa acuta*. **A–B**, *L. natalensis*: **A**, tricuspid lateral teeth; **B**, multicuspid marginal teeth. **C–D**, *P. acuta*: **C**, central portion of radula showing the characteristic arrangement of teeth in physid snails, viz. in oblique rows diverging from either side of the mid-line (arrowed); **D**, multicuspid marginal teeth.
(Scale bars: A = 0.008 mm, B = 0.1 mm; C = 0.05 mm; D = 0.01 mm).

Fig. 3.6. Part of a trail of feeding marks left by *Bulinus tropicus* as it moved over an alga-coated glass surface. Three marks are shown and within each one, the scrapes of individual cusps can be seen. (Scale bar = 0.25 mm).

rocks or submerged vegetation, all southern African freshwater bivalves are free-living burrowers and lie partly buried in sand or mud with their posterior ends protruding. The openings or siphons carrying the inhalant and exhalant water currents are therefore raised above the sand and will not carry sand grains into the mantle cavity. This allows water to flow in unhindered via the inhalant current, carrying both food and dissolved oxygen, over the large plate-like gills and then out again via the exhalant current. These mussels are filter feeders. Food particles reaching the gills become trapped in mucus strands that are passed by means of tiny cilia to a pair of labial palps, which sort the collected particles into acceptable food, which is passed to the mouth, and unacceptable particles, which are diverted to the exhalant current for disposal.

Predation

Despite their protective shells, freshwater snails are preyed upon by a variety of predators. These include obligatory snail feeders such as leeches of the family Glossiphoniidae and the larvae of marsh flies of the family Sciomyzidae. Other predators such as triclad turbellarians (e.g. *Dugesia* spp.), the larvae and adults of certain waterbugs (Family Belostomatidae), the larvae of several beetle families (Hydrophilidae and Lampyridae) and crabs of the genus *Potamonautes*, are less prey-specific. Similarly fish such as the bream *Sargochromis codringtoni* and the barbel *Clarias gariepinus* and ducks feed commonly on snails, but also eat other animals. Large apple snails such as *Lanistes ovum* (Ampullariidae) are often eaten by Openbill Storks, *Anastomus lamelligerus*, and the shells of snails killed by these birds show characteristic damage, viz. a wedge-shaped chip taken out of the lip of the basal whorl. Mussels of the families Unionidae and Mutelidae are also eaten by openbill storks and their shells are damaged in a similar way but on their ventral margins. Smaller bivalves are eaten by fish such as barbel. Amongst mammals, both the banded mongoose and the water mongoose have been seen feeding on mussels, but only on those stranded by receding water levels.

Parasitism

Like all animals, freshwater molluscs may be infected with several types of parasites. Best known are the larval stages of trematodes (flukes), such as those that cause diseases like bilharzia and fascioliasis, but molluscs are hosts to parasitic protozoons and nematodes as well. Their roles as intermediate hosts in the life-cycles of disease-causing trematodes mean that several species of freshwater snail are of great economic importance (see Table 3.1).

The most common protozoan parasites of snails are amoebae of the genus *Hartmanella*. These are intracellular parasites that accumulate in fibrous nodules, usually in the body wall of the foot or mantle collar but also in the wall of the intestine. They have been reported from several species of *Bulinus* and *Biomphalaria* and it is likely that heavy infections of these protozoons will affect the host snail's growth, reproduction and susceptibility to other parasites.

Many different kinds of trematode larvae have been reported as developing in freshwater snails in southern Africa but the life-cycles of very few of these parasites are known. The larvae can generally be found in the gonads and digestive glands of their hosts and feed on these organs. They seldom kill their hosts but in most cases, infections reduce the host snails' growth rates causing them to have shorter life-spans than uninfected snails do. However it has been reported that growth of infected snails may sometimes be accelerated and that some become unusually large (referred to as gigantism). In such cases, the parasite may be able to capitalize on the greater food supply and space within which to develop! Fecundity generally drops and may even cease and the viability of eggs may decrease as well. This is at least partly due to interference by the parasite with the

Table 3.1. Freshwater snails that serve as intermediate hosts of trematode parasites of medical and veterinary importance, or that are invasive or potentially invasive.

Species	Intermediate host	Status as invader
Pomacea bridgesi		Potentially invasive
Pomacea lineata		Potentially invasive
Marisa cornuarietis		Potentially invasive
Tarebia granifera	Asian lungworm *Paragonimus westermani*	Potentially invasive
Lymnaea natalensis	Liver fluke *Fasciola gigantica*	
Lymnaea truncatula	Liver fluke *Fasciola hepatica*	
Lymnaea columella	Liver flukes *F. gigantica* and *F. hepatica*	Invasive
Biomphalaria pfeifferi	Intestinal bilharzia fluke *Schistosoma mansoni*	
Bulinus africanus globosus	Urinary bilharzia fluke *Schistosoma haematobium*	
Bulinus tropicus	Conical fluke of cattle *Calicophoron microbothrium*	
Bulinus forskalii	Conical fluke of horses *Gastrodiscus aegyptiacus*	
Physa acuta		Invasive
Aplexa marmorata		Invasive

functioning of the snail host's albumen gland, which supplies nutrients to the eggs. Rates of infection with trematode larvae seldom exceed 10%.

Besides the well-known trematode parasites mentioned above, molluscs serve as hosts to a variety of other parasites. Few nematodes use freshwater molluscs as intermediate hosts but one noteworthy exception is *Angiostrongylus cantonensis*. The larval stages of this nematode develop in many species of marine, terrestrial and freshwater snails and bivalves and will infect a final host, usually a rat, after it has eaten an infected mollusc. Species of *Pila, Bellamya, Melanoides, Lymnaea* and *Biomphalaria* have been infected experimentally. *A. cantonensis* can also infect humans and cause eosinophilic meningitis. The disease is rare in Africa, although it is spreading at an alarming rate in other parts of the world.

Several annelids should be mentioned here as well. The glossiphoniid leeches, some of which feed on and commonly kill pulmonate snails, can also be found in the mantle cavities of larger gastropods, such as *Lanistes ovum,* and bivalves, such as *Spathopsis wahlbergi,* but probably cause them little harm, being commensals rather than parasites. Although probably not parasitic, the carnivorous oligochaete *Chaetogaster limnaei* (Naididae) is often found crawling on freshwater snails or their shells. This small oligochaete is about 1 mm long and lives inside the snail's mantle cavity or under the lip of its shell, presumably as a commensal, and has been reported to feed on organisms such as trematode miracidia and cercariae on or near the host snails. *Chaetogaster limnaei* has a cosmopolitan distribution.

Habitat Preferences and Ecology

Prosobranch snails have a functional gill and therefore need to be submerged in order to breathe. They are often found on sandy or muddy substrata and may form major components of the bottom-dwelling animal communities of waterbodies, particularly large ones. Pulmonates are generally associated with aquatic plants and are therefore most often found among marginal, emergent or submerged vegetation. Their physiological plasticity, and especially their ability to breathe air (in addition to extracting dissolved oxygen from water), equips them well for surviving fluctuations in water level and in habitats that have dried out. It is at least partly because of this that pulmonates such as *Bulinus forskalii* and *B. depressus* can survive in temporary waterbodies as well as in perennial ones.

Prosobranchs such as *Lanistes ovum* and *Pila occidentalis* can survive in the dry sand or mud of seasonal pools and streams (providing it remains aerobic) for several months at a time by entering a state of aestivation.

When the waterbody is refilled and the sediments become anaerobic, the snails resume activity and quickly start to lay eggs. It is in situations such as these that being a hermaphrodite is a distinct advantage. Indeed, many planorbids, particularly in the genus *Bulinus*, can aestivate succcessfully for up to about six months during periods of drought and *B. forskalii* and *B. scalaris* may sometimes be the only pulmonates living in temporary habitats. Bivalves such as *Unio* and *Spathopsis* also have the ability to aestivate.

Differences in the physical and chemical characteristics of water can greatly affect the shape and appearance of freshwater molluscan shells, even within a small area. One result of this is that, because these habitats are often isolated with little genetic exchange between them, recognizable populations of species develop having shells of particular shapes and localized distributions. An example is the designation of four sculpturally distinct 'morphs' of the thiarid snail *Melanoides tuberculata* by Pointier (1989). This should be remembered when using the key below to identify specimens.

Bottom dwelling prosobranch snails may be abundant. In Lake Kariba, for example, *Melanoides tuberculata*, *Bellamya capillata* and *Cleopatra nsendweensis* can reach densities of 2300/m^2, 300/m^2 and 100/m^2 respectively at depths of 4–6 m. Lower densities can be expected in other types of waterbody. *Pila occidentalis* and *Cleopatra* sp. were sampled at 15–20/m^2 in the shallows of the Kavango River, Namibia, and the pulmonate *Melampus semiaratus* at a mean density of 52/m^2 (maximum 310/m^2) in the Beachwood mangrove swamp, Durban. Among the bivalves, the small sphaeriid *Pisidium* may often be found at about 100/m^2 in different waterbodies such as streams and lakes in South Africa though densities of up to 798/m^2 have been recorded. The larger Corbiculidae, Unionidae and Mutelidae are more or less restricted to lakes, dams and perennial rivers and may also be present in large numbers. Population densities of 30–50/m^2 have been reported for species of *Coelatura*, *Spathopsis* and *Mutela* and 100–1100/m^2 for *Corbicula* from habitats as diverse as Lake Kariba, the Okavango Delta and the pans of the Pongolo River floodplain in northern KwaZulu–Natal. The brackwater bivalve *Hiatula lunulata* has been recorded at densities up to 4600/m^2 in the Hlabane estuary in KwaZulu–Natal. The river oyster, *Etheria elliptica*, occurs only in rivers, and is usually found in dense clusters on rocks in rapids, but usually well below the surface. In waterbodies such as these, although bivalves are seldom seen, they dominate the benthos and since they are capable of filtering large volumes of water, must play an important role in nutrient cycling.

The only snails known from saline lakes and pans in southern Africa belong to the genus *Tomichia* (Pomatiopsidae), which occurs along the southern and south-eastern coastal strip. Several species are tolerant of increasing salinities up to about 25 as the water dries up (Davis 1981). One species, *T. ventricosa*, is however particularly euryhaline and can live in hypersaline water, up to 50 for a month at least. Hundreds of individuals per square metre have been recorded in some pans.

Molluscs living in the lowest reaches of rivers or at the upper ends of lagoons and estuaries will be subjected to fluctuations in salinity in accordance with the tidal cycle. Most snails found here are prosobranchs and include brackwater species such as *Septaria tessellaria*, *Thiara amarula* and *Neritina natalensis* as well as essentially marine species such as *Littoraria subvittata* and *Assiminea ovata*. Despite their marine origins, they are all able to tolerate salinities ranging from close to zero (<1) to nearly full strength sea water (35) for varying periods. Pulmonate snails are less common in these areas but it has been shown, for example, that *Bulinus africanus*, the intermediate host for the urinary bilharzia parasite, can live in salinities up to approximately 3.5, although it cannot breed under such conditions. It is therefore possible that the disease could be transmitted in these upper reaches of estuaries (Donnelly et al. 1983).

Freshwater bivalves can also tolerate high salinities. The mussel *Unio caffer* may occur in salinities up to 3 but, again, it is doubtful whether it can breed under such conditions. It is possible however that its glochidial stage could be carried from one river to another via the sea while parasitic on euryhaline fish such as the mullet *Liza euronotus* and the kurper *Oreochromis mossambicus*. The sunset clam, *Hiatula lunulata*, is an example of a marine bivalve that has become adapted to the low salinities of the upper parts of lagoons and estuaries and, as noted earlier, may occur there at high densities.

Southern African mangrove swamps support a small but characteristic mollusc fauna consisting of about 10 species of snail, all but three of which are prosobranchs. The three exceptions are members of the pulmonate family Ellobiidae. They occur most commonly on and in the mud amongst the pneumatophores and on the trunks of *Avicennia marina*, and may possibly also be found on other mangrove species. They are not, however, restricted to mangrove swamps. Bivalves are not found in southern African mangrove swamps although marine oysters may be attached to mangrove trees. In general however, the mollusc fauna of the brackish reaches of rivers and mangrove swamps along the eastern and south-eastern coasts of South Africa is poorly known and merits special attention.

ECONOMIC IMPORTANCE

A number of snail species is of economic importance in southern Africa, serving as intermediate hosts for trematode parasites of medical and veterinary importance or being invasive or potentially so. They are listed in Table 3.1. Not listed are the genera shown experimentally by Richards & Merritt (1967) to be susceptible to *Angiostrongylus cantonensis*. Potential invasiveness is based on reports on the same species from other countries to which they have been introduced. The environmental impact of the three invasive species is not understood.

The indigenous Ampullariidae and perhaps some of the larger bivalves may be of value as a food resource in rural areas. Indeed, *Spathopsis wahlbergi*, *S. petersi*, *Coelatura kunenensis* and *C. mossambicensis*, and snails such as *Lanistes ovum*, have been found, sometimes in large numbers, by archaeologists excavating Iron Age midden deposits. As mentioned above, they are edible and were probably collected for food. These molluscs have an average calorific content of 100–575 kJ, roughly equivalent to between four and 20 grams of peanut butter, depending on their size! Eaten in quantity therefore they would certainly be nutritious but are probably too slow-growing to be harvested on a sustainable basis. Empty bivalve shells may also have been used as tools for burnishing clay pots and made into beads.

CONSERVATION

The conservation of South Africa's mollusc fauna was recently discussed in detail by Herbert (1998). Compared with other regions of the continent, few southern African freshwater mollusc species are considered to be endangered. The IUCN Red List of Threatened Animals (Baillie & Groombridge 1996) lists only the genus *Tomichia* (Pomatiopsidae), with two species in the 'Threatened' category at least partly because of the destruction of their coastal habitat. In addition, *Tomichia cawstoni* is listed in the 'Extinct and Extinct in the Wild' category but was recently discovered in a forest stream in the Eastern Cape (D.G. Herbert, pers. comm.). This is an atypical habitat for *Tomichia* and suggests that we know all too little about these tiny snails. Several other species are likely to be endemic to southern Africa and thus of priority for conservation. The planorbid *Gyraulus connollyi* is confined to the southern African highveld and upper parts of the eastern escarpment and *Segmentorbis angustus* has been reported only from the eastern coastal lowlands and may therefore also be endemic. Amongst the bivalves, *Pisidium harrisoni* may be endangered and *Unio caffer* is not only endemic to southern Africa but its range in the south-western Cape has decreased in recent years.

Criticism has been leveled at the use of molluscicides to kill bilharzia-carrying snails and this practice is becoming increasingly controversial, even where it forms part of integrated bilharzia control programmes. Molluscicidal chemicals have seldom been used in South Africa except in small-scale trials (Appleton 1985), largely because snail control has not been shown unequivocally to be effective in reducing transmission of the disease anywhere. The harmful effects of molluscicides on non-target molluscs and fish are recognized, as is their high cost, so that it is unlikely that they will be used on a routine basis in this country. Rather they may have limited use, mostly in artificial habitats such as irrigation canals and night storage dams on farms, where transmission of the disease is often intense.

COLLECTING AND STUDY TECHNIQUES

Freshwater molluscs are most successfully collected by means of a shallow, long-handled scoop net. A stainless steel mesh fitted inside a steel frame (alternatively a kitchen sieve will do quite well) mounted on a long handle has proved ideal for collecting amongst vegetation and in sand or mud. Bivalves can be collected by means of a long-toothed rake. Floating pieces of wood or even palm leaves can be used as snail traps. These need to be left in the water for a week or so until a growth of periphyton has formed on them before they will become attractive to snails. Research in West Africa (Kpikpi et al. 1996) has shown that natural products, especially sugarcane, may be useful as attractants or baits.

Live specimens can be kept in glass aquaria and fed on dried lettuce leaves mixed with commercial fish flakes. The water should be changed once a week and aerated to ensure that it contains a high level of dissolved oxygen. A piece of blackboard chalk dropped into the water will provide a supply of calcium carbonate for shell construction. Tap water should not be used until it has been aged for 48 hours to allow all chlorine, which is toxic, to dissipate. Heavy metals are also poisonous to molluscs and water which has flowed through copper or zinc pipes should be avoided.

Specimens to be stored for scientific study should be relaxed (narcotized) and fixed before being preserved, especially when the soft parts are required for dissection. Prosobranch snails are best relaxed by placing them in a 0.1% solution of nembutal (a sodium-pentabarbitone anaesthetic) for 36 hours. A recommended procedure for pulmonates (Paraense 1986) is to immerse them partially for about 20 seconds into hot water (approx. 70 °C) spire first so as to minimize retraction into the shell, then plunge them completely into the water for an additional 20 seconds after which they should be transferred to water at room temperature. The soft parts can then be removed under water with forceps, fixed in

Railliet-Henry's solution for 48 hours and preserved in 70% ethanol. Alternatively pulmonates can be relaxed by adding either a few menthol crystals or a drop of a solution of menthol crystals dissolved in chloral hydrate to the surface of the water in a petri-dish containing the snails and leaving for 24–36 hours.

Once relaxed, snails belonging to either subclass can be fixed in 5% buffered formalin for 48 hours before being transferred to 70% ethanol for storage. Long-term storage in formalin is not recommended because the solution is acidic and dissolves the shell. The arrangement of teeth in the radula and number of cusps on them are useful aids to identification, particularly in the large and medically-important genus *Bulinus*. A method for extracting and preparing a radula is outlined in Appleton (1996). Once prepared, it should be examined under the high power lens (40x) of a compound microscope or, better still, a scanning electron microscope.

Bivalves do not generally require to be relaxed but their closed valves can be made to open by placing them in warm water and heating until boiling. The soft parts can then be removed easily and fixed and preserved as described above.

KEY TO THE FAMILIES OF SNAILS AND BIVALVES

Keys to the genera and species of freshwater snails of southern Africa have been published during the past 50 years by Alves & Clark (1953), van Eeden (1960), Brown & Kristensen (1989) and Appleton (1996). These, like the books by Brown (1980, 1994), which also contain keys, can often only be found in reference libraries in universities and museums and are not readily available to local users. Mandahl-Barth (1988) provided a key to the freshwater bivalves of Africa.

The key given below allows the identification of both snails and bivalves to family level because the genera and species within each family are, for the most part, sufficiently distinctive to be identified on illustrations alone. Conchological (shell) characters are used in most cases and can be seen in both living animals and empty shells. The main features of snail and bivalve shells are illustrated in Figs 3.1C & 3.3B. There are many different types of opercula in prosobranch snails and two of the most common are illustrated in Fig. 3.2. A 10x hand-lens or low power of a dissecting microscope are necessary to see fine sculpture such as that found on the apices of the shells of the limpets *Burnupia* and *Ferrissia* and the hinge teeth and growth lines of the small mussels of the families Corbiculidae and Sphaeriidae. Some easily recognizable anatomical characters are also used.

To identify a specimen, first classify it to family level using the key below and then turn to the more detailed notes and figures on the family in question in order to complete the identification. The notes accompanying these figures sometimes use numerical indices of shell shape to describe the outline of a shell. These indices involve making various measurements and expressing them as ratios, viz. the shell height/width (H/W) ratio for snails (Fig. 3.1C) and the shell length/height (L/H) ratio for bivalves (Fig. 3.3B). The ranges of ratios given in these descriptions include approximately 90% of the specimens likely to be found.

Measurements should be made to the nearest 0.1 mm, preferably using a Vernier Caliper for large specimens, or through a dissecting microscope fitted with a measuring eyepiece for small ones. It is useful to rest small shells on a little fine sand in a watch glass placed on the stage of the microscope. This allows the shell to be turned easily so as to see and measure different aspects accurately. Where anatomical characters are used, these are best observed on live or narcotized specimens. Although identification of *Bulinus* spp. requires the dissection of specimens, this is not generally the case for other genera.

The notes following the key below give information on the morphology (including maximum recorded shell dimensions), biology and distribution of each species within southern Africa and indicate those of economic importance. All introduced and invasive snail species are included. To date, no freshwater bivalves are known to have been introduced to southern Africa.

KEY TO THE FAMILIES OF FRESH- AND BRACK-WATER MOLLUSCA KNOWN FROM SOUTHERN AFRICA

1. Shell consisting of one piece (univalve) (Class **Gastropoda**: snails and limpets, e.g. Figs 3.8A & 3.14D respectively) 2
– Shell consisting of two valves joined by a hinge (Class **Bivalvia:** mussels and oysters, e.g. Figs 3.20C & 3.22A & B) 20

2. Aperture closed by a spirally or concentrically constructed operculum (Fig. 3.2), shell usually robust and calcareous (Subclass **Prosobranchia**: e.g. Fig. 3.8A) 10
– Aperture not closed by an operculum, shell usually thin and corneous (Subclass **Pulmonata**: e.g. Fig. 3.14A) 3

3. Shell limpet-like (Figs 3.14D–G) with apex inclined to the right hand side, not spirally coiled .... **Ancylidae** (p. 88)
– Shell not limpet-like, spirally coiled (e.g. Fig. 3.18D) 4

4. Whorls laid down in one plane making the shell discoid in shape .... **Planorbidae** (Subfamily **Planorbinae**) (p. 90)
– Whorls not laid down in one plane 5

5. Shell dextral (aperture on observer's right hand side when spire pointing upwards: e.g. Fig. 3.14A) 6
– Shell sinistral (aperture on observer's left hand side when spire pointing upwards: e.g. Fig. 3.18E) 8

6. Shell thick, columella with one or several distinct folds within the aperture (Figs 3.13D–F)... **Ellobiidae** (p. 84)
– Shell thin, columella without any folds 7

7. Columellar axis narrowly reflexed and generally twisted where it joins the parietal region (Figs 3.14A–C); only one pair of triangular tentacles with eyes at their bases; aquatic or amphibious ....**Lymnaeidae** (p. 85)
– Columellar axis neither reflexed nor twisted where it joins the parietal region (Fig. 3.13C); two pairs of tentacles with eyes at the tips of the posterior pair; semi-aquatic.. **Succineidae** (p. 82)

8. Shell turriform in shape (Fig. 3.18G) ....**Planorbidae** (Subfamily **Bulininae**, in part) (p. 96)
– Shell ovate or acuminate in shape (e.g. Fig. 3.18B) 9

9. Spire blunt; texture matt; suture appears as a single line; pseudobranch present (Fig. 3.18C); blood coloured red due to pigment haemoglobin; foot rounded posteriorly and uniformly grey (Figs 3.18B, D–G)................ .... **Planorbidae,** (Subfamily **Bulininae**, in part) (p. 96)
– Spire (Figs 3.19A–C) sharply pointed, texture glossy, suture appears as a double line, pseudobranch absent, blood colourless due to haemocyanin, foot pointed and darkened posteriorly .... **Physidae** (p. 100)

10. Shell sinistral (aperture on observer's left hand side when spire pointing upwards) (Fig. 3.9A)........................... **Ampullariidae** (in part) (p. 71)
– Shell dextral (aperture on observer's right hand side when spire pointing upwards) 11

11. Shell hemispherical, spire very low or hidden, shell consisting of only a few whorls, which increase gradually in diameter; no umbilicus (Fig. 3.7).......... .... **Neritidae** (p. 67)
– Shell ovate, acuminate or turriform, spire well-developed, several whorls gradually increasing in diameter, umbilicus present (e.g. Fig. 3.1C) 12

12. Shell globose, oval or conical , height less than 25 mm 13
– Shell conical, height greater than 25 mm 14

13. Shell (Fig. 3.11B) brown and smooth, height up to 10 mm....................... ....**Assimineidae** (p. 78)
– Shell yellowish with wavy darker markings, sculpture spiral (Fig. 3.10A), height up to 25 mm .... **Littorinidae** (p. 74)

14. Sutures between whorls shallow giving shell a smooth outline, height up to 120 mm 15
– Sutures between whorls deep giving spire a stepwise outline (Figs 3.9B–D) height up to 50 mm ....**Ampullariidae** (in part) (p. 71)

15. Aperture with siphonal canal; height up to 120 mm; found in brack water, salt marshes or mangroves (Figs 3.13A–B)........................ **Potamididae** (p. 81)
– Shell aperture without siphonal canal, height up to 45 mm, found in fresh water 16

16. Shell with sculpture of spiral rows of tubercules, ribs or striae (Figs 3.12A–F) .... **Thiaridae** (in part) (p. 79)
– Shell smooth 17

17. Shell with dark spiral bands (Fig. 3.12G)............ **Thiaridae** (in part) (p. 79)
– Shell uniform whitish/beige in colour 18

18. Shell small (<10 mm in height) 19
– Shell (Fig. 3.8) medium-sized (10–20 mm in height) ..... **Viviparidae** (p. 70)

19. Shell usually turriform, with a corneous operculum ....**Hydrobiidae** (Fig. 3.10B) and **Pomatiopsidae** (Figs 3.10 C–D)
– Shell ovate (Fig. 3.11A), with a calcareous operculum ....**Bithyniidae** (p. 78)

20. Adults usually >20 mm in height, valves usually thick, inner surface nacreous, hinge with cardinal teeth plus a posterior lateral tooth or with cardinal teeth only or without teeth 21
– Adults usually <20 mm in height, valves thin, inner surface not nacreous, hinge with cardinal teeth and both anterior and posterior lateral teeth 25

21. Hinge with cardinal and posterior lateral teeth (Figs 3.20D, G).... **Unionidae** (p. 102)
– Hinge with cardinal teeth only or lacking teeth 22

22. Hinge with cardinal teeth only (Fig. 3.23I) .... **Psammobiidae** (p. 115)
– Hinge without teeth 23

23. Animal free-living in sandy or muddy substrata, valves symmetrical, may be iridescent green .... **Mutelidae** (Fig. 3.21) (p. 106)
– Animal not free living but attached to submerged objects or substrata either by its lower valve or by means of byssus threads; valves not always symmetrical 24

24. Animal sedentary with lower valve cemented to hard substrata; valves rough, variable and not symmetrical (Figs 3.22A–B)............... **Etheriidae** (p. 109)
– Animal attached to substratum by means of a tuft of brown byssus threads, valves symmetrical, with a fine, ribbed sculpture on antero-posterior quadrant (Figs 3.20A–B) .... **Mytilidae** (p. 101)

25. Valves robust; hinge strongly developed, two or three radially-arranged cardinal teeth and long, crenellated lateral teeth in both valves; shell with sculpture of strong concentric ribs (Figs 3.22C–E).......................**Corbiculidae** (p. 110)
– Valves fragile; hinge weakly developed, one or two cardinal teeth in each valve, lateral teeth short and not crenellated or only weakly crenellated; shell smooth except for growth lines (Figs 3.23A–G)............**Sphaeriidae** (p. 111)

ILLUSTRATED NOTES ON FAMILIES, GENERA AND SPECIES

Snails and bivalves are arranged systematically according to the schemes used by Brown (1994) and Mandahl-Barth (1988) respectively. Discoidal shells are drawn from both left and ventral views. In most cases, illustrations of bivalve shells show the external views of left valves but representative internal views of the hinge plate of the opposing right valve are shown for most genera as well. Where sizes are given for shells, these are the largest on record (in millimetres) and relate to maximum height and maximum width for snails (e.g. 25 x 10) and maximum length and width for bivalves (e.g. 100 x 45). In some cases a third measurement, width, is given for bivalves as well. This relates to the combined width of both valves held together in the closed position as in life. In common with other animals and plants, many of the molluscs found in southern Africa, particularly the northern and eastern parts, will occur further north as well.

CLASS GASTROPODA
SUBCLASS PROSOBRANCHIA
FAMILY **NERITIDAE**

Figs 3.7A–G

A family of generally medium-sized snails typically with a low spire, thick shell, closed umbilicus and calcareous operculum. Sexes are separate. Many members are marine but two genera occur in the lowest, often brackish, reaches of rivers in Mozambique, KwaZulu–Natal and the Eastern Cape (Transkei). Their distributions may be wider than indicated below.

Neritina

Four species of *Neritina* occur on the coastal plain of south-eastern Africa. Adults are usually within the size range 15–20 x 20–23 mm; the shell is thick and hemispherical, the aperture D-shaped and the operculum calcareous with a small rib and peg (apophysis) projecting from its inner surface. The well-developed glossy white columella is a conspicuous feature.

Neritina gagates Lamarck, 1822
Fig. 3.7A

Characteristic features

A thick black/brown periostracum overlies a pattern of paler zig-zag lines but these are generally not visible and the shell appears uniformly black.

Distribution

Recorded near the coast from Mozambique to Mzamba in the former Transkei (Eastern Cape).

Neritina natalensis Reeve, 1855
Fig. 3.7B

Characteristic features

Yellow/brown with dark anastomosing bands and spots of varying intensity.

Distribution

Recorded from the coastal lowlands of Mozambique and KwaZulu–Natal southwards to the Umzimkulu River (Lat. 30° 40′ S).

Neritina pulligera (Linnaeus, 1767)
Fig. 3.7C

Characteristic features

Shell appears uniformly black but a fine reticulate pattern may be visible; spire completely hidden. An orange band is usually present around the inner margin of the aperture. Grows up to 22.5 x 29.9 mm.

Distribution

Recorded from shallow streams along the coastal plain of Mozambique and KwaZulu–Natal as far south as Durban.

Another species with its spire obscured, *N. auriculata* Lamarck, 1816 (not illustrated), has fine spiral sculpture and spiral black and white banding. It is known from northern KwaZulu–Natal to the Umtamvuna River.

Septaria

Two species of *Septaria* occur in South Africa but their distributions are not well known. The shape and colour of their shells are variable.

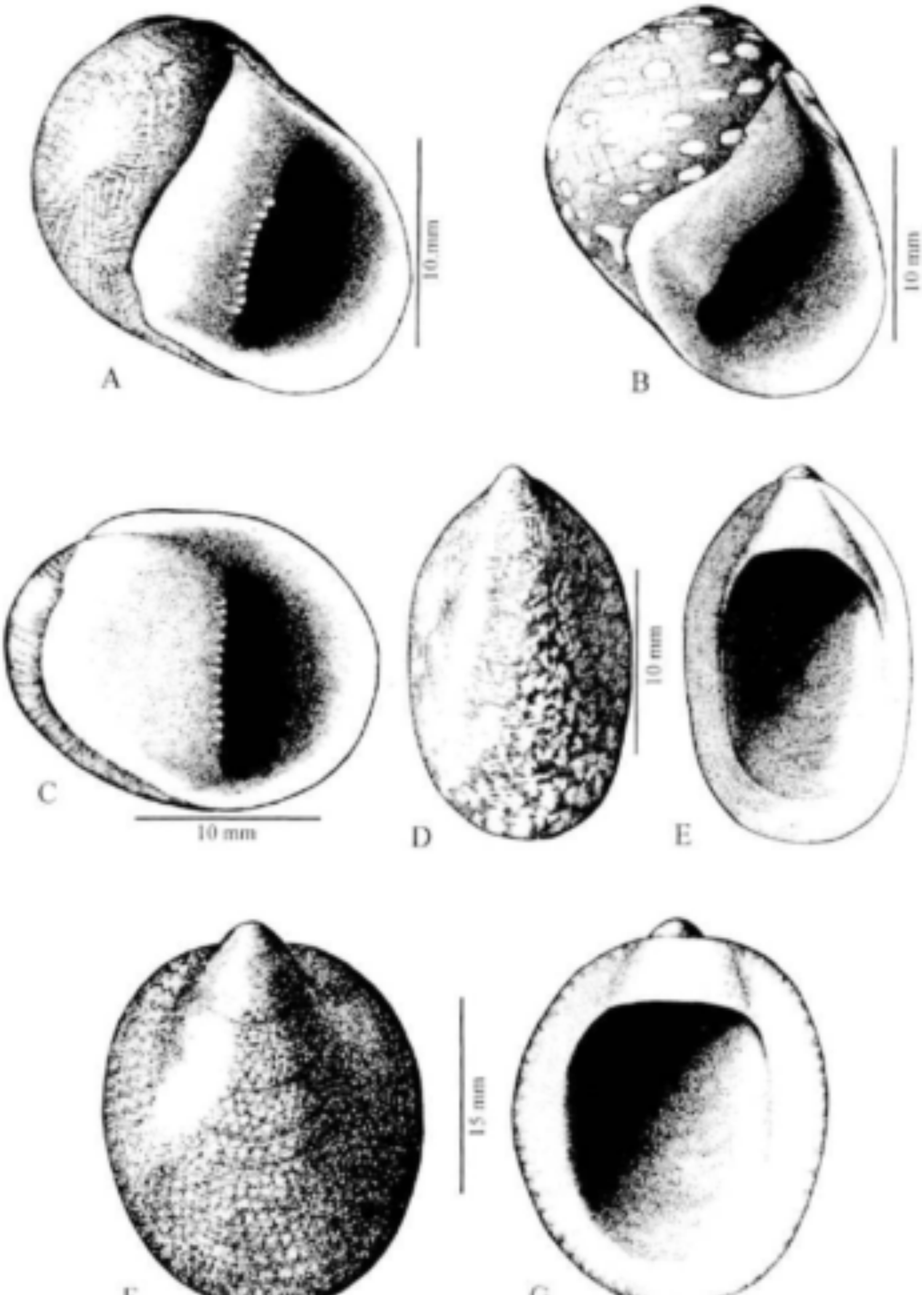

Fig. 3.7. Neritidae, shells: **A**, *Neritina gagates*; **B**, *N. natalensis*; **C**, *N. pulligera*; **D**, *Septaria tessellaria* (apical view); **E**, *S. tessellaria* (underside view); **F**, *S. borbonica* (apical view); **G**, *S. borbonica* (underside view).

Septaria tessellaria (Lamarck, 1816)
Fig. 3.7D & E

Characteristic features

A limpet-like, elongate (size 23 x 14 x 6 mm; H/W ratio 1.64), pale brownish shell with a darker reticulate pattern, apex posteriorly situated with a cavity beneath. Slender forms occur on reed stems, broader ones on rock.

Distribution

Recorded from the lower reaches of KwaZulu–Natal rivers from Amanzimtoti to Southbroom.

Septaria borbonica (Bory de St Vincent, 1803)
Fig. 3.7F & G

Characteristic features

Shell oval to nearly circular (size 30 x 25 x 10 mm; H/W ratio 1.20), ground colour dark brown with darker markings, apex prominent with deep cavity beneath.

Distribution

Occurs in streams close to sea level northwards from Tongaat and Mtunzini on the KwaZulu–Natal north coast.

FAMILY **VIVIPARIDAE**
Figs 3.8A & B

Medium-sized snails with dextral, turbinate shells, concentric, corneous opercula and whorls, which are typically angular at their shoulders. Two species have been recorded from southern Africa.

Bellamya capillata (Frauenfeld, 1865)
Fig. 3.8A

Characteristic features

Shell uniform pale brown, measuring up to 31 x 24 mm, aperture almost circular, umbilicus closed. Sexes are separate, females viviparous but since no males were found in populations from north-eastern KwaZulu–Natal (Joubert 1977), they may sometimes be parthenogenetic.

Distribution

The Okavango and Zambezi Rivers and the eastern lowlands southwards to the Pongolo River floodplain and Lake Sibaya in north-eastern KwaZulu–Natal.

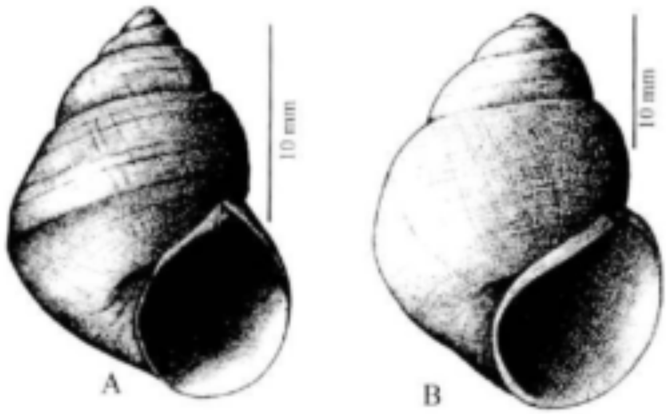

Fig. 3.8. Shells of species of Viviparidae: **A**, *Bellamya capillata*; **B**, *Bellamya monardi*.

Remarks

A second species, *B. monardi* (Haas, 1934) (Fig. 3.8B), occurs in the Kunene and Okavango Rivers of northern Namibia but apparently not commonly. It has not been found in the wetlands of eastern Caprivi (Namibia) or the Okavango delta in Botswana.

FAMILY **AMPULLARIIDAE**
Figs 3.9A–F

Sometimes called the Pilidae, this family comprises large animals in shells greater than 20 mm in height, usually globose and smooth. The operculum is concentric with its nucleus lying close to the columella; the umbilicus is narrowly open. Sexes are separate. Species are found in both permanent and temporary water bodies where they are able to aestivate in dried mud for several months. Known as 'apple' or 'mystery' snails in the aquarium trade. Two indigenous genera, *Lanistes* and *Pila*, and two introduced genera, *Pomacea* and *Marisa*, occur in southern Africa. *Pila* and *Pomacea* may be difficult to separate on shell characters since they are both globose and banded but the structure of the operculum and relative length of the siphon are useful diagnostic features. The operculum in both genera is corneous but in *Pila* it has a thin calcareous layer on the inside while in *Pomacea* it is entirely corneous. The siphon of *Pila* is shorter and less flexible than in *Pomacea*.

Lanistes ovum Peters, 1845
Fig 3.9A

Characteristic features

Large (up to 59 x 44 mm), sinistral, uniformly olive green to brown shells. Operculum corneous. It became a pest in rice paddies in Swaziland in the 1960s, eating the growing tips of young rice plants.

Distribution

Recorded from the Okavango River system in the north-west to the lowlands of the east and southwards to the Pongolo River floodplain.

Pila occidentalis (Mousson, 1887)
Fig 3.9B

Characteristic features

Large (up to 49 x 41 mm), dextral snails, shell green/brown with about 10 darker spiral bands; operculum corneous but with an inner calcareous layer.

Distribution

In southern Africa it is confined to the Okavango and Kunene River systems of northern Namibia and Botswana.

ALIEN AMPULLARIIDS: *MARISA* AND *POMACEA*

Marisa and *Pomacea* are South American genera of dextral Ampullariidae that have been imported into South Africa via the aquarium trade. Although presently confined to artificial environments, species in these genera have the potential to invade natural waters in southern Africa. *Marisa* is unique in the family in that its shell is discoidal. The shells of *Pomacea* spp. are similar in shape and colour to the indigenous *Pila*, but colour is a poor guide because, although the wild type (natural) pattern is pale brown with dark spiral bands, yellow varieties of *P. bridgesi* and another species *P. canaliculata*, have been bred by aquarists. Two varieties of *Pomacea bridgesi* are thus available in pet shops as 'mystery' and 'yellow' or 'golden mystery' snails respectively. The soft parts are normally grey/brown but pale in albino forms. Three species of *Pomacea* have become invasive in other countries. They are, however, difficult to separate but the spire height/shell height ratio is useful for identification (Table 3.2). The spires of specimens from habitats other than aquaria are often eroded.

Pomacea bridgesi (Reeve, 1856)
(Alien species) Fig. 3.9C

Characteristic features

Measures up to 52 x 40 mm. Shoulder of basal whorl generally flat with the sutural angle nearly 90°. Colour may be either wild-type (banded) or uniform yellow.

Distribution

Not recorded outside aquaria and ornamental ponds where it is probably the more common of the two species reported from South Africa. Has become invasive in Hawaii (Cowie 1993).

Pomacea lineata (Spix, 1827)
(Alien species) Fig. 3.9D

Characteristic features

Native to Brazil, this species grows to 38 x 30 mm, has a pale brown shell with 5–6 darker spiral bands on the basal whorl and thus resembles the indigenous *Pila occidentalis*. Shoulder of basal whorl not flat and sutural angle usually greater than 90°.

Distribution

Occurs in ornamental ponds and was collected in an impounded stream in Westville, Durban, in 1989.

Remarks

Although not recorded from South Africa, *Pomacea canaliculata* (Lamarck 1822), which is very close to *P. lineata* in terms of anatomy and shell morphology (Thiengo et al. 1993), has become invasive in several Asian countries, and in Hawaii and Florida, where it causes severe damage to rice crops. May reach a shell height of 57 mm but compared to *P. bridgesi* it has a relatively low spire (Table 3.2).

Table 3.2. Comparative spire height/shell height ratios (ranges and means) for *Pomacea bridgesi*, *P. canaliculata* and *P. lineata* from South America

Species	Spire height/shell height
P. bridgesi	0.25 – 0.38 (0.34)
P. calaliculata	0.18-0.33 (0.28)
P. lineata	0.10-0.18 (0.13)

Marisa cornuarietis (Linnaeus, 1758)
(Alien species) Fig. 3.9E & F

Characteristic features

Known in the aquarium trade as the giant ramshorn snail, it has a dextral shell superficially similar to those of the discoid Planorbidae but grows very much larger, up to 42 x 18 mm or more. Has a variable colour pattern of prominent concentric stripes or bands.

Distribution

This species is endemic to northern South America but was imported into South Africa for research purposes. Only known from laboratories, it is a herbivore and could cause serious ecological damage if allowed into natural waterbodies. Has become invasive in canals associated with the Everglades in Florida as well as in Cuba and Puerto Rico. It was introduced to Egypt, Sudan and East Africa as part of attempts to control the snail hosts of bilharzia and has become locally established.

FAMILY **LITTORINIDAE**

Fig. 3.10A

Littorinids are small snails usually associated with the splash-zone of rocky sea shores. Some species are tolerant of changing salinity and exposure patterns and occur in river mouths, lagoons and estuaries, where they live between the high spring tide mark and the mean tide level in mangrove swamps and salt marshes.

Littoraria subvittata Reid, 1986
Fig. 3.10A

Characteristic features

Shell height 13–34 mm with 40–60 ribs on the basal whorl.

Distribution

This species occurs commonly from the Swartkops River mouth at Port Elizabeth northwards to Mozambique. It is often found together with *L. intermedia*, which is similar but can be distinguished by the larger number of ribs on the basal whorl of the shell.

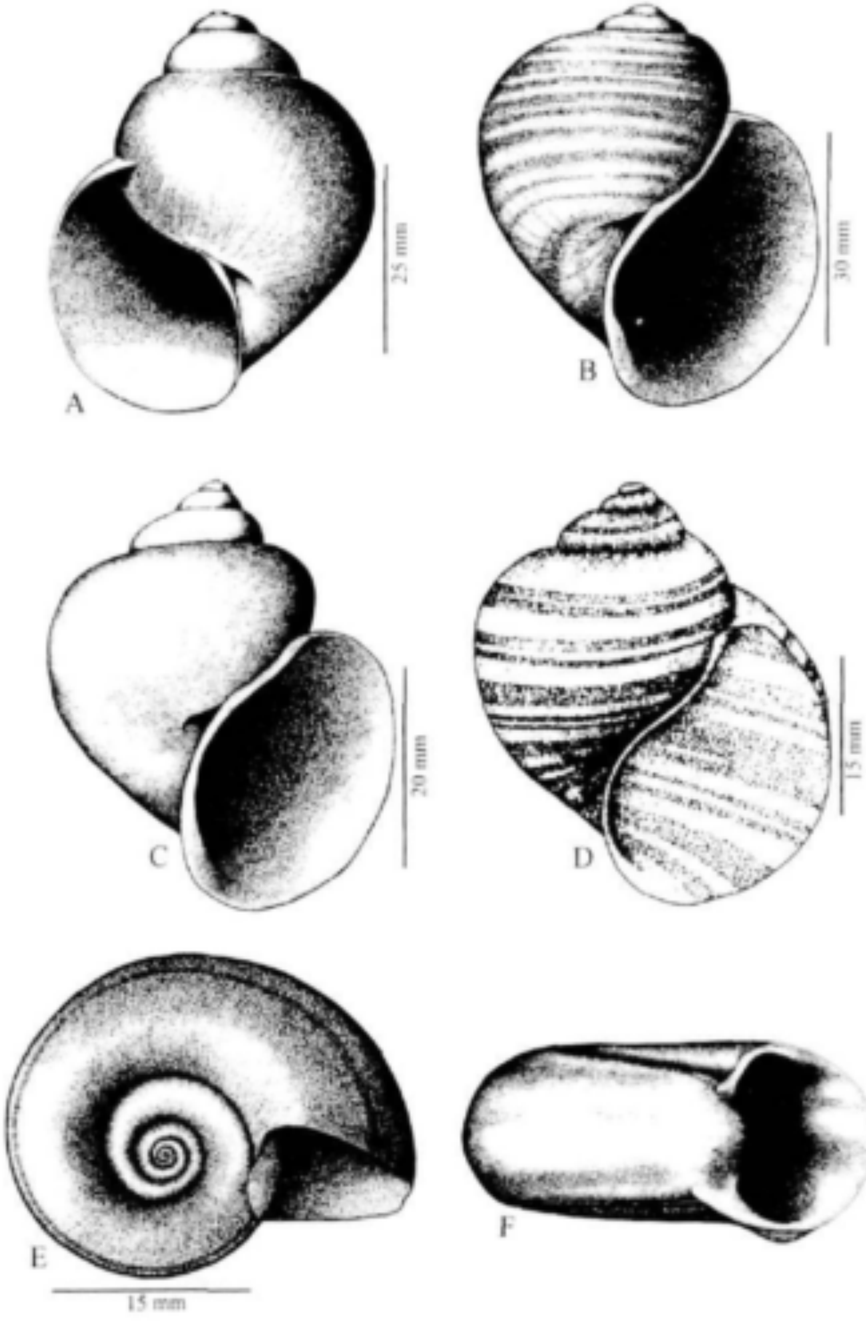

Fig. 3.9. Shells of species of Ampullariidae: **A**, *Lanistes ovum*; **B**, *Pila occidentalis*; **C**, *Pomacea bridgesi*; **D**, *P. lineata*; **E–F**, *Marisa cornuarietis*: **E**, apical view; **F**, apertural view.

Littoraria intermedia (Philippi, 1846)
(not illustrated)

Characteristic features

Shell height 14–26 mm with 17–21 ribs on the basal whorl.

Distribution

Found from Transkei (Umtata River mouth) to Mozambique.

FAMILY **HYDROBIIDAE**

Fig. 3.10B

Small, pale brown shells, height up to 10 mm, spire well developed, operculum corneous, with few spirals. One genus, *Lobogenes*, occurs in southern Africa.

Lobogenes michaelis Pilsbry & Bequaert, 1927
Fig. 3.10B

Characteristic features

Shell small, height less than 5 mm with a well-developed spire, central region of outer margin of basal whorl produced forward when viewed in profile. The umbilicus is closed.

Distribution

Occurs mainly in the Zaire River catchment but with a single record from the wetlands of eastern Caprivi in Namibia, which represents its southernmost locality in Africa.

FAMILY **POMATIOPSIDAE**

Figs 3.10C & D

Studies by Davis (1981) showed that the genus *Tomichia* belongs in the family Pomatiopsidae and not, as previously thought, the Hydrobiidae. The two families are closely related and superficially similar in appearance, anatomy and habits. Sexes are separate.

Seven species of the genus *Tomichia* are recognized from southern Africa and all are endemic. Their shells are elongate and generally less than 10 mm in height, and vary in colour from whitish to dark brown. The umbilicus is closed in many species. *Tomichia zwellendamensis* (Küster, 1852) (Fig. 3.10C) is considerably more slender than most of the other species (e.g. Fig. 3.10D). Members of the genus occur, sometimes abundantly, on the coastal lowlands from the Cape Peninsula to Empangeni in KwaZulu–Natal, often in brackwater habitats.

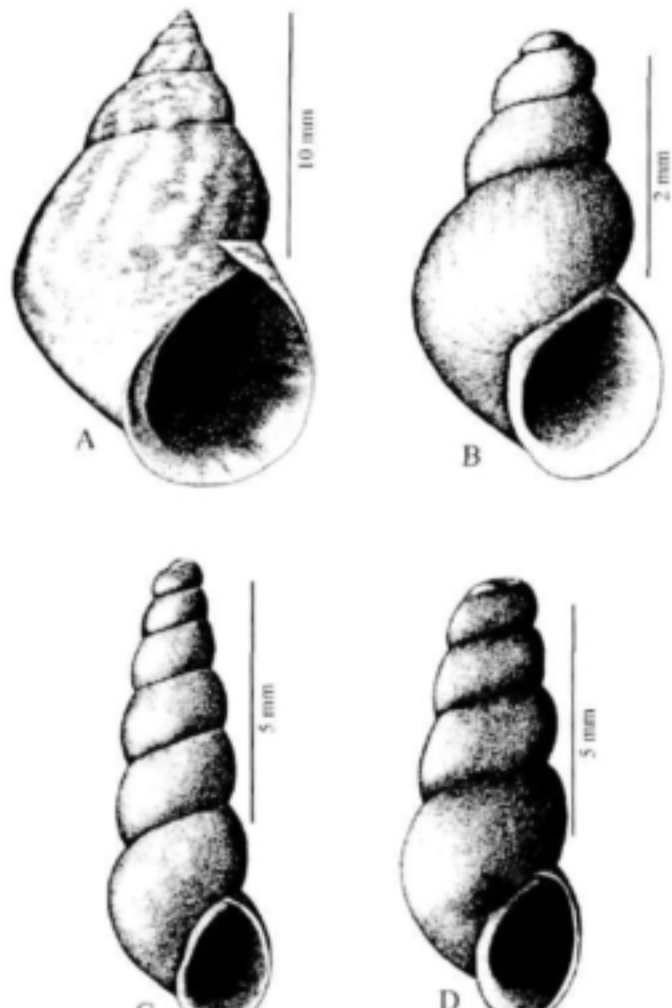

Fig. 3.10. Shells of species of Littorinidae, Hydrobiidae and Pomatiopsidae. **A**, Littorinidae, *Littoraria subvittata*. **B**, Hydrobiidae, *Lobogenes michaelis*. **C–D**, Pomatiopsidae: **C**, *Tomichia zwellendamensis*; **D**, *Tomichia* sp.

FAMILY **BITHYNIIDAE**

Fig. 3.11A

Small snails, shell depressed but with a distinct spire; operculum calcareous. Sexes separate, females oviparous. One species occurs in southern Africa.

Gabiella kisalensis (Pilsbry & Bequaert, 1927)

Fig. 3.11A

Characteristic features

Shell small, globose and pale brown (up to 6 mm in height) with a concentric, calcareous operculum. Umbilicus narrowly open.

Distribution

A central African species reaching its southernmost limit in the delta of the Okavango River in Botswana.

FAMILY **ASSIMINEIDAE**

Fig. 3.11B

These 'sentinel snails' are typically small, less than 10 mm in height. They have brown shells with well-developed spires and are common on mud flats of river mouths, estuaries, salt marshes and mangroves. There are several species but these are difficult to separate. One species extends into brack waters.

Assiminea ovata (Krauss, 1848)

Fig. 3.11B

Taxonomic note

Formerly known as *Assiminea bifasciata* Nevill, 1880.

Characteristic features

A variable species, being banded in Natal but unbanded in the eastern and southern Cape. Umbilicus closed, operculum corneous. Tolerant of wide salinity and depth ranges, viz. from almost fresh to sea water and from above the water level to depths of about 3 m.

Distribution

River mouths, estuaries and lagoons from Knysna to Mozambique.

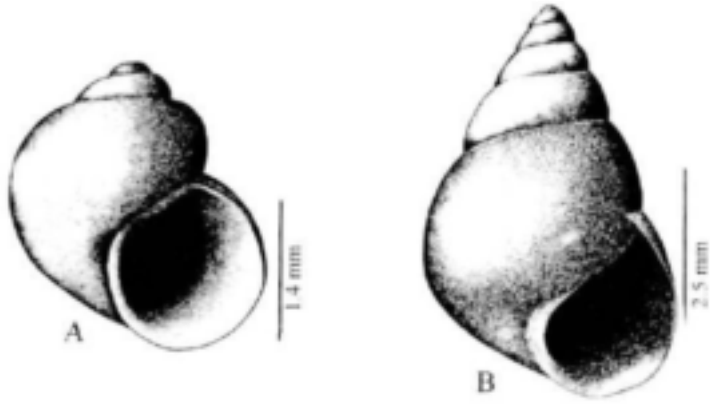

Fig. 3.11. Shells of species of Bithyniidae and Assimineidae. **A**, Bithyniidae: *Gabiella kisalensis*. **B**, Assimineidae: *Assiminea ovata* .

FAMILY **THIARIDAE**
Figs 3.12A–G

A large family consisting of medium-sized snails with shells of variable shape and with a well-developed spire, usually thick-shelled with strong sculpture. Operculum corneous but variable in form. The tip of the spire is often eroded. Umbilicus closed. Sexes separate but males may be lacking and females parthenogenetic. Four genera — *Thiara, Tarebia, Melanoides* and *Cleopatra* — occur in southern Africa.

Thiara amarula (Linnaeus, 1758)
Figs 3.12A & B

Characteristic features

An unmistakable species, up to 38 x 20 mm in height, with its sculpture of transverse ribs usually projecting as blunt tubercles on the shoulders of the whorls, colour uniform grey/black. Spire of adult shell always eroded (Fig. 3.12A); tubercles remain sharp on shells of juveniles up to 20 mm (Fig. 3.12B).

Distribution

Found in the lower reaches of KwaZulu–Natal and Mozambique rivers where salinities are generally in the 0–15 range. It is not known whether populations can become established in habitats without any tidal influence but specimens have been kept in freshwater aquaria for many months.

Tarebia granifera (Lamarck, 1816)
(Alien species) Fig. 3.12C

Characteristic features

An Asian species discovered in KwaZulu-Natal in 1999, but apparently introduced several years earlier. The source of introduction is unknown. The largest specimen collected had a shell height of 22 mm. Pale brown to dark brown, tubercles well marked and tip of spire usually worn. Populations are entirely female, parthenogenetic and ovoviviparous. It becomes reproductively mature at an age of about 22 months (shell height *ca.* 13 mm).

Distribution

Known only from a reservoir in Mandeni, northern KwaZulu-Natal, where it was abundant, reaching an average density of about $1000/m^2$.

Remarks

It is not known whether *T. granifera* has spread into the nearby Tugela River system. If it has, it is likely to become invasive as happened following introductions in the Caribbean and elsewhere. Previously called *Thiara granifera.*

Melanoides tuberculata (Müller, 1774)
Figs 3.12D & E

Characteristic features

A common turriform species measuring up to 45 x 13 mm. Sculpture varies from strong axial ribs and spiral grooves with tubercles, sometimes with reddish flame-like markings (Fig. 3.12E) to smoother individuals with less prominent ribs (Fig 3.12D). Males rare, females parthenogenetic and ovoviviparous. Reaches reproductive maturity at about 6 months (shell height about 10 mm).

Distribution

Occurs in isolated localities in Namibia but more extensively in the eastern lowlands and south to the Eastern Cape. It is not known from either the Kunene or Okavango river systems or east Caprivi. This species is also indigenous to India and the southeast Asian mainland to northern Australia.

Remarks

This species has become plentiful in rice paddies in KwaZulu-Natal and has also been found in some subterranean waters in Namibia. An apparently identical snail is commonly sold by aquarists and may be the 'Malayan snail' mentioned in books on tropical fish-keeping.

Melanoides victoriae (Dohrn, 1865)

Fig. 3.12F

Characteristic features

Superficially similar to *M. tuberculata* with which it may co-occur but sculpture is less prominent, especially on the basal whorl.

Distribution

Common in the Kunene and Okavango Rivers and east Caprivi but less so in the Okavango delta and Mpumalanga lowveld. Not known from KwaZulu–Natal.

Cleopatra

This is a genus of distinctive pale brown snails whose shells have several spiral dark brown bands on most whorls. Size up to 20 x 12 mm. The operculum is corneous and concentric with a small spiral nucleus. Three species are known from southern Africa. Two occur in the northern parts of Namibia and Botswana, the third in Zimbabwe and eastern South Africa. *Cleopatra elata* Dautzenberg & Germain, 1914 occurs in the Okavango River, its delta and the wetlands of East Caprivi. *Cleopatra nsendweensis* Dupuis & Putzeys, 1903 occurs in the Kunene, Okavango (but not the delta) and the upper Zambezi River systems including lake Kariba. Neither of these is illustrated. The third, *C. ferruginea* (Lea, 1850) (Fig. 3.12G) is found in the Zambezi River below Lake Kariba, the lowlands of Mozambique, Limpopo, Mpumalanga, Swaziland and north-eastern KwaZulu–Natal where it has colonised concrete-lined irrigation canals. It can be recognized by having deeper sutures than the other species and a spiral ridge on the upper 3–4 whorls.

FAMILY **POTAMIDIDAE**

Figs 3.13A & B

Medium to large snails with elongate, sculptured shells. Species of *Cerithidea* and *Terebralia* are typical members of the fauna of mangrove swamps, where they are amphibious, moving in and out of the water, on the mud and on mangrove trunks. Three species, two of which are illustrated here, occur in southern Africa. The third, *Potamides conicus* (de Blainville, 1826), does not extend south of Mozambique.

Cerithidea decollata (Linnaeus, 1767)
Fig. 3.13A

Characteristic features

An unmistakable species. It grows up to 38 x 18 mm in size and has a brown shell with many conspicuous ribs. Shells of adults always have an eroded apex.

Distribution

Known from mangrove swamps and occasionally from salt marshes from Mozambique to the mouth of the Keurbooms River, west of Port Elizabeth.

Remarks

These snails are found commonly in aggregations of hundreds on mangrove trunks between the high and low neap tide marks, hence the name 'climbing whelk'. They descend to the mud to feed, chiefly over the periods (6–7 days) before and after neap tides, thereby perhaps avoiding predation by crabs and fish (Cockroft & Forbes 1980). Juveniles occur mostly on the mud.

Terebralia palustris (Linnaeus, 1767)
Fig. 3.13B

Characteristic features

The 'mangrove whelk', a large, handsome species measuring up to 80 x 25 mm, with a sharply pointed shell. Tolerant of a wide salinity range.

Distribution

Occurs on mud in some but not all lagoons and mangrove swamps along the KwaZulu–Natal and Eastern Cape (Transkei) coasts to the Mngazana estuary. This species occurred in the Bayhead Mangrove Swamp in Durban Bay until about 1991.

SUBCLASS PULMONATA
FAMILY **SUCCINEIDAE**
Fig. 3.13C

A terrestrial family, the so-called 'amber snails', with thin, dextral shells and two pairs of tentacles. Umbilicus closed, hermaphroditic. Sometimes confused with members of the family Lymnaeidae.

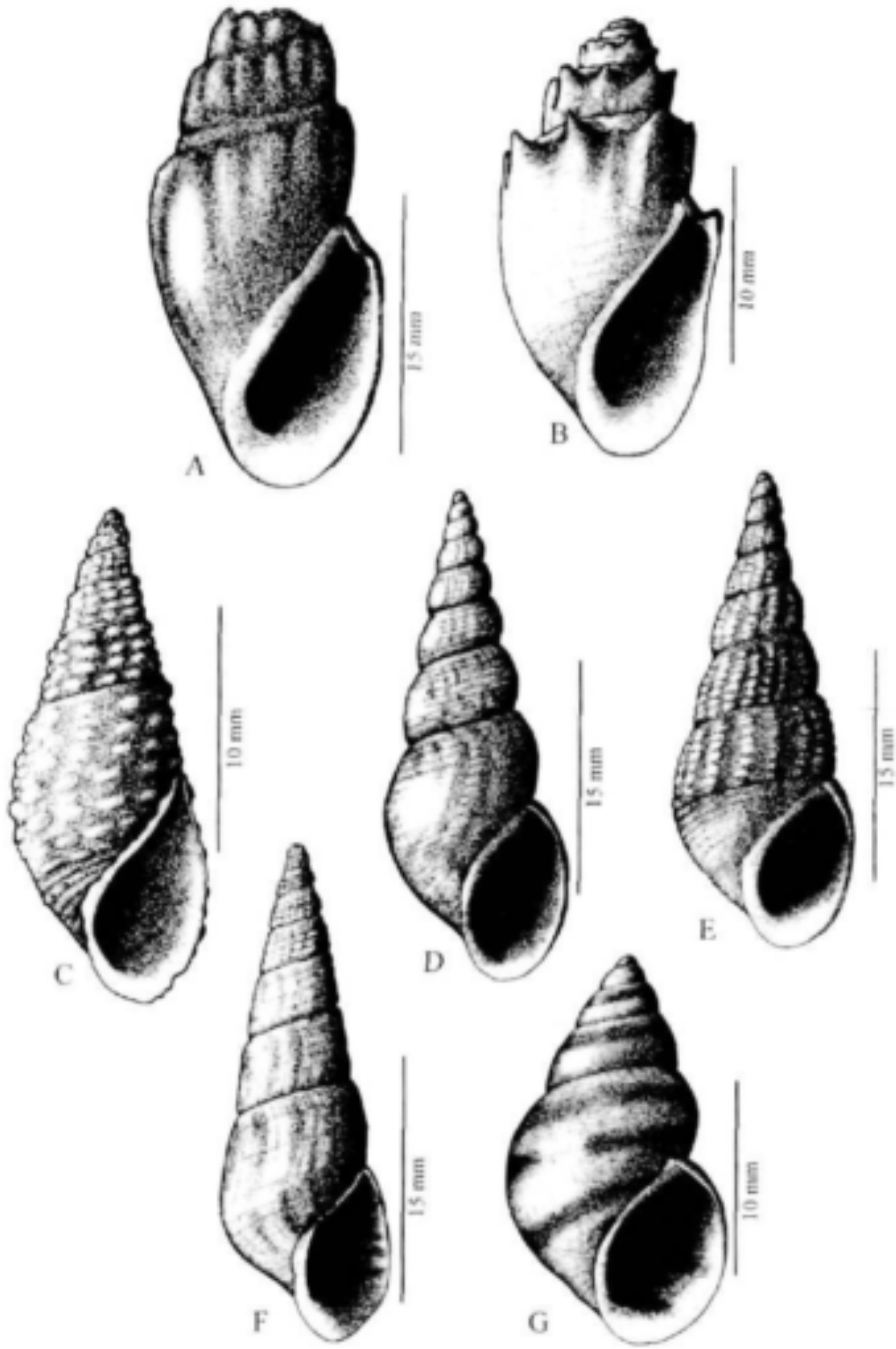

Fig. 3.12. Shells of species of Thiaridae. **A–B**, *Thiara amarula*: **A**, adult; **B**, juvenile. **C**, *Tarebia granifera*. **D–E**, *Melanoides tuberculata*: **D**, weakly sculptured form; **E**, strongly sculptured form. **F**, *Melanoides victoriae*. **G**, *Cleopatra ferruginea*.

Oxyloma patentissima (Pfeiffer, 1853)
Fig. 3.13C

Characteristic features

A semi-aquatic species, growing up to 10 x 6 mm. Aperture is very large.

Distribution

Commonly found on emergent vegetation alongside water and is often collected while netting for aquatic animals. Found from Mozambique southwards to the KwaZulu–Natal south coast and across the highveld to North West province, northern Botswana and Zimbabwe. Common in the upper panhandle of the Okavango delta.

FAMILY **ELLOBIIDAE**

Figs 3.13D–F

Small to medium-sized, amphibious snails with comparatively thick shells that may appear at first glance to be prosobranchs. They are usually amphibious and species belonging to the genera *Auriculastra, Cassidula* and *Melampus* are commonly found in brack water close to river mouths. They also occur in mangrove swamps.

Auriculastra radiolata (Morelet, 1860)
Fig. 3.13D

Characteristic features

Shell smooth, shiny, translucent and pale greenish-brown in colour and measuring up to 12 x 5 mm. Apex usually eroded. Two folds on the inner margin of aperture, the upper more prominent than the lower.

Distribution

A burrowing species found to depths of up to 150 mm in mud below mangrove trees on the KwaZulu–Natal coast.

Cassidula labrella (Deshayes, 1830)
Fig. 3.13E

Characteristic features

Shell smooth, brown and up to 12 x 7 mm in size. Sutures between whorls difficult to see due to presence of many fine, concentric grooves. Aperture with 2–3 folds on inner margin and one on outer lip.

Distribution

Occurs on the mud surface in salt marshes and mangrove swamps from KwaZulu–Natal southwards to Port Elizabeth.

Melampus semiaratus Connolly, 1912
Fig. 3.13F

Characteristic features

Shell smooth, uniform brown, but with spiral grooves on upper and lower parts of each whorl. Spire usually eroded in larger specimens. Inner margin of aperture with 1–2 ridges and white bands on its outer margin. Colour dark brown and grows to 10 x 6 mm.

Distribution

Found in crab holes to a depth of about 150 mm and on mud beneath mangrove trees along the coast of KwaZulu–Natal and Mozambique.

FAMILY **LYMNAEIDAE**
Figs 3.14A–C

Of the three species of *Lymnaea* occurring in southern Africa, one has been introduced. Two species are amphibious in habit and can often be found on the damp sand or mud just above the waterline but their eggs require to be laid beneath the water. This family is characterized by a columellar axis narrowly reflexed and generally twisted where it joins the parietal region. The umbilicus is closed. Only one pair of triangular tentacles with eyes at their bases.

Lymnaea natalensis Krauss, 1848
Fig. 3.14A

Characteristic features

Grows up to about 22 x 14 mm, basal whorl usually markedly swollen. Sculpture consisting of growth lines only.

Distribution

Found over the eastern half of the sub-continent south of latitude 20°S as well as the Gariep (Orange), Okavango and Zambezi River systems and the south-eastern coastal strip (also see de Kock & Wolmarans 1998 for a distribution map). Shells from the Okavango River system are noticeably slender and both shell and soft parts often pale pink in colour.

Remarks

For a detailed study of the species' anatomy, see Pretorius & van Eeden (1969). Serves as the major intermediate host of the giant liver fluke *Fasciola gigantica*.

Lymnaea columella Say, 1817
(Alien species) Fig. 3.14B

Taxonomic note

Sometimes called *Pseudosuccinea columella*.

Characteristic features

This species grows up to 16 x 9 mm. The basal whorl is distinctly swollen but not as much as in *L. natalensis* and its sculpture consists of growth lines and spiral ridges producing a characteristic reticulate pattern.

Distribution and habitat preferences

An amphibious, North American species that is commonly found on the damp mud at the water/air interface. De Kock et al. (1989) provided a distribution map.

Remarks

L. columella has invaded many southern African river systems. It is believed to serve as an intermediate host for *Fasciola hepatica* and *F. gigantica*. Since its distribution in South Africa is wider than that of either parasite, it may have enabled fascioliasis to spread to these areas.

Lymnaea truncatula (Müller, 1774)
Fig. 3.14C

Characteristic features

Basal whorl not markedly swollen, spire approximately as high as the aperture, sculpture of growth lines only, shell <10 mm in height.

Distribution and habitat preferences

Occurs mostly in the high altitude areas (>800m) of southern and central South Africa, including Lesotho (distribution map given by de Kock & Wolmarans 1998). Its habitat requirements were discussed in detail by Prinsloo & van Eeden (1974); generally the species is amphibious, occurring in swamps and bogs but rarely in rivers or open pools.

Remarks

Serves as the major intermediate host for the common liver fluke, *Fasciola hepatica*.

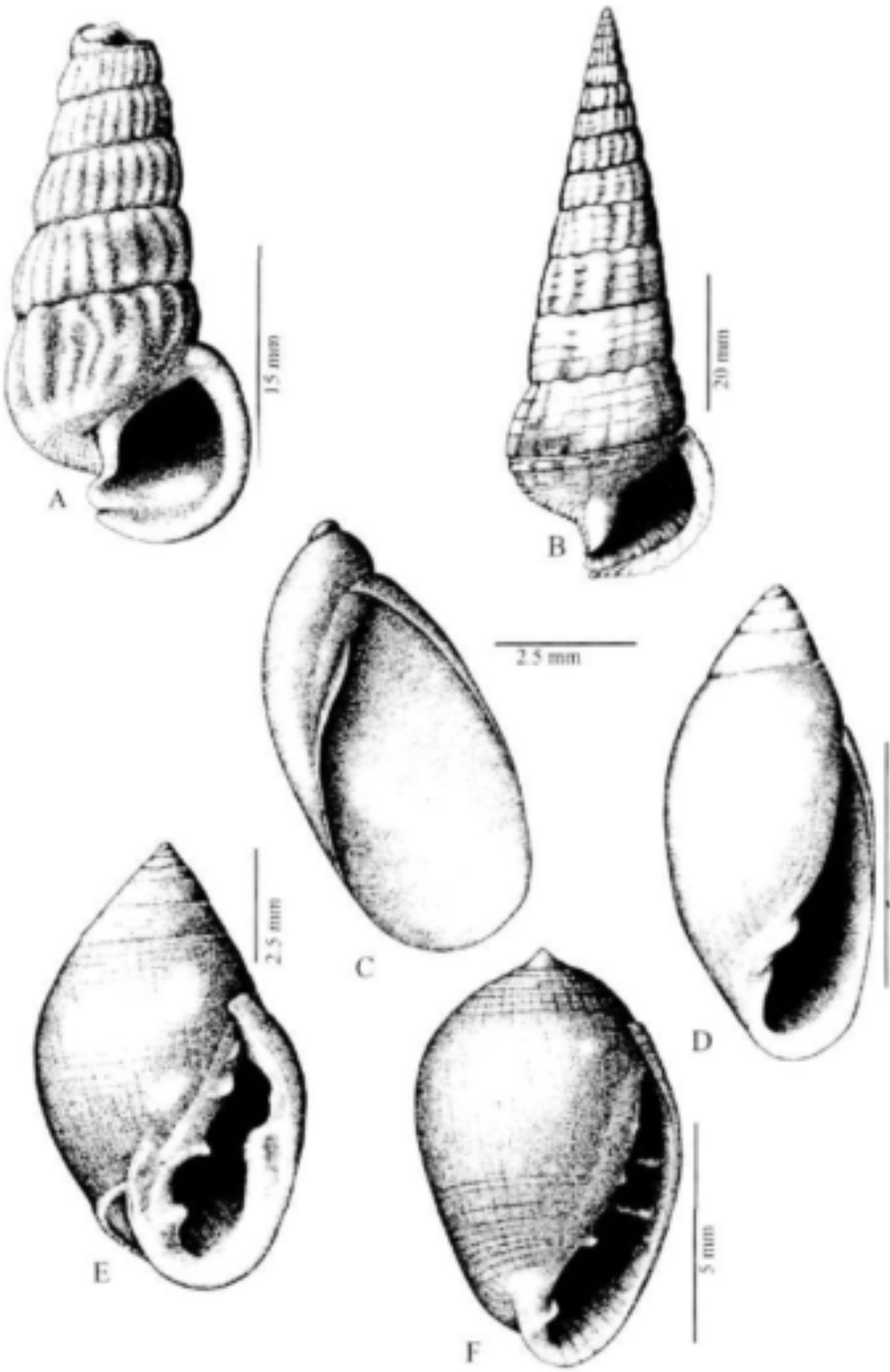

Fig. 3.13 Shells of species of Pomatiidae, Succineidae and Ellobiidae. **A–B**, Pomatiidae: **A**, *Cerithidea decollata*; **B**, *Terebralia palustris*. **C**, Succineidae: *Oxyloma patentissima*. **D–F**, Ellobiidae: **D**, *Auriculastra radiolata*; **E**, *Cassidula labrella*; **F**, *Melampus semiaratus*.

FAMILY **ANCYLIDAE**

Figs 3.14D–G

Shell small, sinistral and limpet-like (patelliform) with the apex posterior and inclined to the right hand side. Since the shells of ancylids have no columella, the columella muscle attachments have separated into three parts though these may sometimes be joined. The two main attachment points lie anteriorly on each side of the mantle and the third near its posterior left hand side. These scars show up well after staining the animal in Lugol's Iodine. Ancylids often occur on rocks and stones in flowing watercourses but may be found in standing water, i.e. pools and lakes, as well. Two genera have been reported from southern Africa, each with numerous described species, which are difficult to distinguish. Revision is needed at both generic and species levels.

Burnupia

Fig. 3.14D & E

Characteristic features

Apex prominent giving the shell a distinctly asymmetrical appearance; apical microsculpture consisting of radial pits; shell up to 10 mm long. Right hand anterior adductor muscle scar usually comma-shaped to elongate; penis without a flagellum.

Distribution

Widely distributed throughout southern Africa except the arid parts of Botswana and Namibia.

Remarks

Fourteen species have been described from the region. Davies-Coleman (2001) studied the breeding biology of *B. stenochorias* (Melvill & Ponsonby 1903) and found that this species could be reared in a laboratory and could be used to quantify biological responses to water quality. Oberholzer & van Eeden (1969) gave a detailed account of the anatomy of *B. mooiensis* (Walker, 1912).

Ferrissia

Figs 3.14F & G

Characteristic features

Apex not prominent so that the shell appears only slightly asymmetrical; apical microsculpture consisting of radial lines; shell up to 5 mm long. Right hand anterior muscle scar small and oval; penis with a glandular flagellum the function of which is unknown.

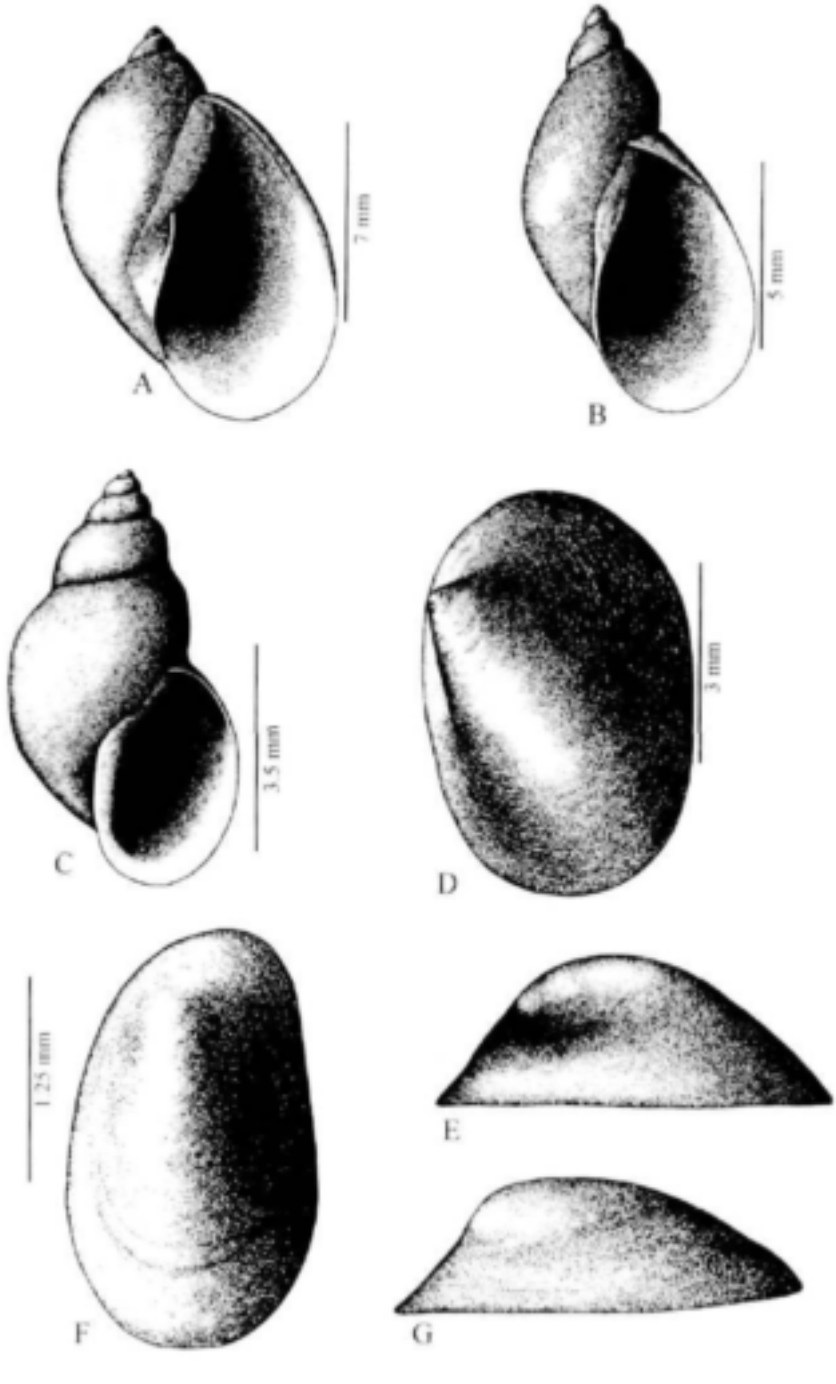

Fig. 3.14. Shells of Lymnaeidae and Ancylidae. **A–C**, Lymnaeidae: **A**, *Lymnaea natalensis*; **B**, *Lymnaea columella*; **C**, *Lymnaea truncatula*. **D–G**, Ancylidae: **D**, *Burnupia* sp. (apical view); **E**, *Burnupia* sp. (lateral view); **F**, *Ferrissia* sp. (apical view); **G**, *Ferrissia* sp. (lateral view).

Distribution

Widely distributed over the sub-continent except for the arid central and western parts.

Remarks

Eleven species have been described from the region.

FAMILY **PLANORBIDAE**

Figs 3.15–3.18

Shell discoid, elongate or helicoid; spire usually well developed; texture usually matt; suture appearing as a single line. Tentacles slender and elongate. Pseudobranch present (see Fig. 3.18C), blood coloured red due to presence of haemoglobin. Seven indigenous genera, *Afrogyrus, Ceratophallus, Gyraulus, Lentorbis, Segmentorbis, Biomphalaria* and *Bulinus*, and two introduced genera, *Helisoma* and *Planorbella*, are found in southern Africa. Scalariform freaks, in which the shell spiral appears unwound, are known in *Ceratophallus* and *Biomphalaria*.

Afrogyrus and ***Ceratophallus***

Characteristic features

Shells discoid, maximum height and diameter of adults not exceeding 2 x 7 mm respectively, whorls gradually increasing in diameter, sculpture of fine growth lines. These two genera are similar in appearance and are best distinguished by dissection of the male genitalia (see Brown 2001).

Distribution

Afrogyrus coretus (de Blainville, 1826) (Fig. 3.15A & B) is at present known only from widely separate localities, viz. north-western Namibia, Okavango delta and north-eastern KwaZulu–Natal, but is probably more continuously distributed. *Ceratophallus natalensis* (Fig. 3.15C & D) is distributed over most of the southern and eastern parts of the region as well as the Okavango Delta.

Gyraulus spp.

Characteristic features

Shell discoid, maximum dimensions not exceeding 2 x 7 mm, whorls increase rapidly in diameter and the aperture may be deflected downwards (see Fig. 3.15F).

Remarks

Two species of *Gyraulus* are found in southern Africa.

Gyraulus connollyi Brown & van Eeden, 1969
Figs 3.15E & F

Characteristic features

Shell with sculpture of fine growth lines, shoulder of basal whorl rounded.

Distribution

Occurs on the southern and central and eastern highveld plateau and the Drakensberg escarpment to an altitude of about 1000 m. South of Port St Johns it is found close to the coast.

Remarks

Endemic to southern Africa.

Gyraulus costulatus (Krauss, 1848)
Fig. 3.15G & H

Characteristic features

Conspicuous sculpture of strong, regularly spaced transverse ribs; shoulder of the basal whorl is distinctly angular.

Distribution

The northern and eastern highveld and KwaZulu–Natal, eastern Zimbabwe and the Okavango River system. May occur sympatrically with *G. connollyi* on the Drakensberg escarpment.

Lentorbis spp.
Fig. 3.16A & B

Characteristic features

The shell is discoid, convex on its dorsal side and concave on its ventral side due to the presence of a deep umbilicus. Shell usually without internal septa but there may be up to four incomplete ones; texture shiny.

Distribution

This genus occurs in the Okavango River system and along the coastal strip of Mozambique and South Africa to approximately 30 °S.

Remarks

Two species are known from southern Africa and are distinguishable on male genital anatomy (see Brown 1994).

Segmentorbis spp.
Fig. 3.16C & D

Characteristic features

Shell similar shell to *Lentorbis* but with up to 10 radial lamellae visible inside the basal whorl.

Distribution

Similar to that of *Lentorbis*.

Remarks

Three species are known from southern Africa but examination of the soft parts is needed to separate them. Like *Lentorbis*, a detailed review of the validity of the described species is needed.

Biomphalaria pfeifferi (Krauss, 1848)
Fig. 3.16E & F

Characteristic features

A medium-sized, umbilicate, discoid shell, height and diameter not exceeding 5 x 17 mm respectively. The periphery of the basal whorl is usually evenly rounded.

Distribution

Common in the Okavango River system, Zimbabwe, southern Mozambique and the eastern parts of South Africa southwards to the Mngazi River in Eastern Cape (Transkei) (distribution map provided by de Kock & Wolmarans 1998).

Remarks

Internal anatomy described by Mandahl-Barth (1958) and Schutte & van Eeden (1960). Serves as the intermediate host for *Schistosoma mansoni*, the parasite that causes intestinal (rectal) bilharzia in man.

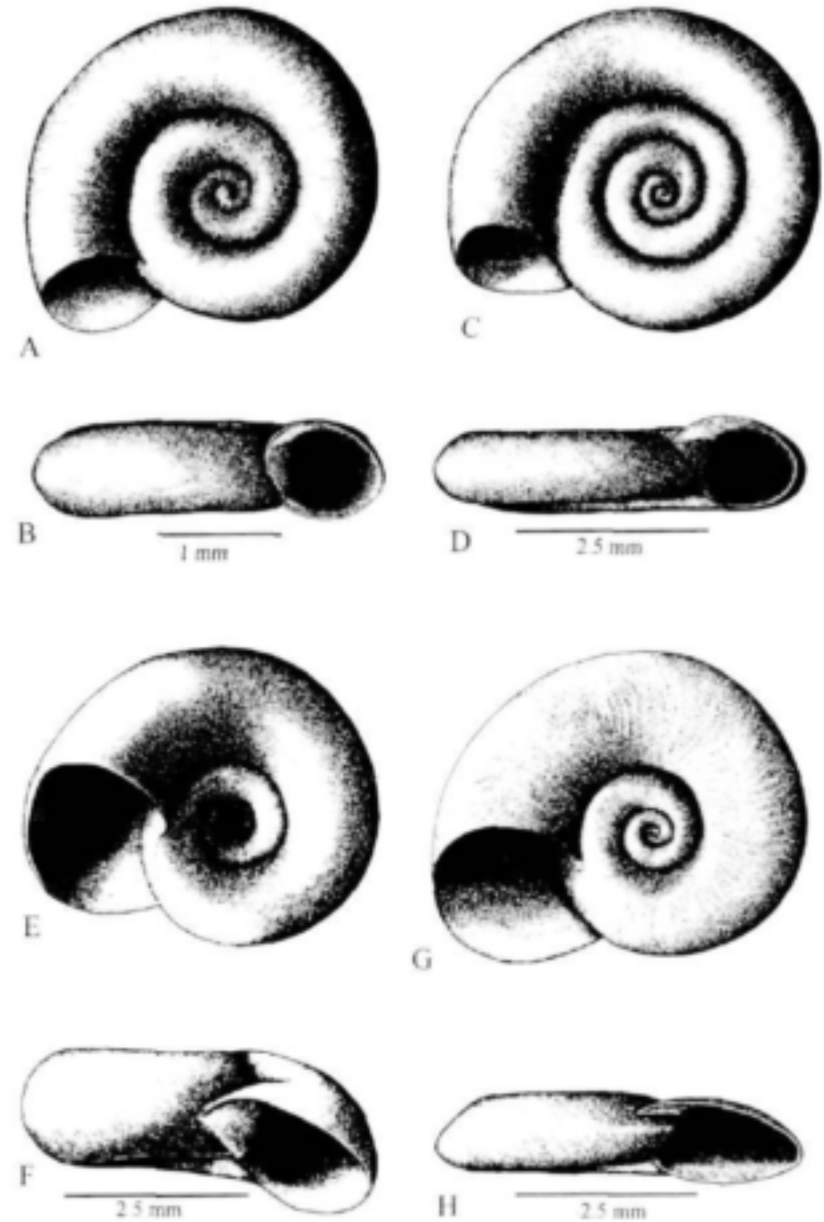

Fig. 3.15 Shells of Planorbidae. **A–B**, *Afrogyrus* sp.: **A**, apical view; **B**, apertural view. **C–D**, *Ceratophallus sp.*: **C**, underside view; **D**, apertural view. **E–F**, *Gyraulus connollyi*: **E**, underside view; **F**, apertural view. **G–H**, *Gyraulus costulatus*: **G**, underside view; **H**, apertural view.

Biomphalaria glabrata (Say, 1818)
(Alien species) Fig. 3.16G & H

Characteristic features

Maximum shell height and diameter dimensions 5–8 and 30–40 mm respectively; periphery of the basal whorl usually angular dorsally.

Remarks

A South American species, which is a very efficient intermediate host for *Schistosoma mansoni* and was imported into South Africa in 1982 for research purposes. Only known from laboratories but could have serious implications for public health if allowed to escape into natural waterbodies, as has happened in Egypt.

Remarks

The genera *Helisoma* and *Planorbella* are similar in appearance to *Biomphalaria* but can be distinguished by examination of the soft parts. *Helisoma* and *Planorbella* spp. have a large preputial (holdfast) organ inside the preputium while *Biomphalaria* does not. This is everted during copulation to ensure contact with the partner. It can easily be found on dissection. Both are Nearctic genera.

Helisoma duryi (Wetherby, 1879)
(Alien species) Fig. 3.17A & B

Characteristic features

Has a characteristically high shell with maximum dimensions (height x diameter) of 9 x 22 mm. Holdfast organ foot-shaped. Albino forms occur with their soft parts orange/red in colour.

Distribution

A North American species introduced into southern Africa via the aquarium industry.

Remarks

Rarely found in natural wetland systems, which is surprising since it is common in aquaria and ornamental ponds. This may be because it is unable to reproduce by self-fertilization, making it ineffective as a colonizer.

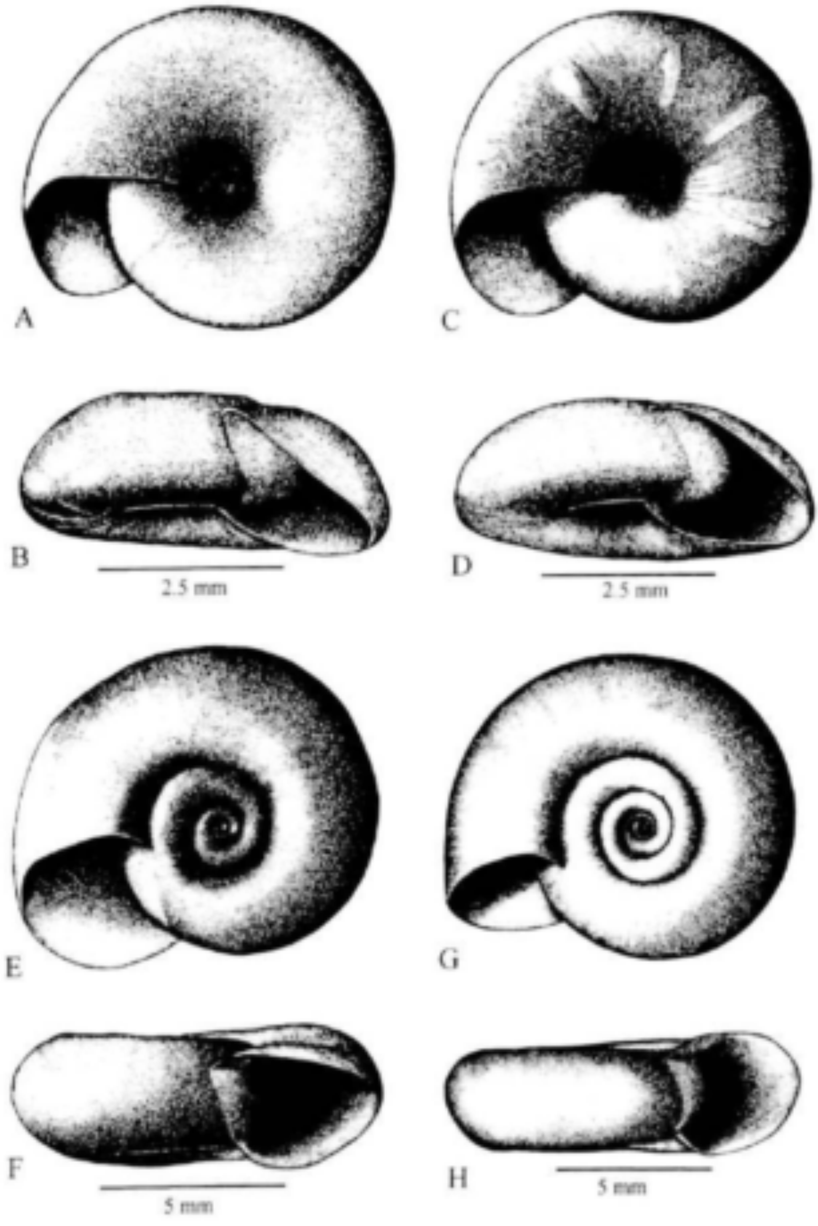

Fig. 3.16. Shells of Planorbidae. **A–B**, *Lentorbis* sp.: **A**, underside view; **B**, apertural view. **C–D**, *Segmentorbis* sp.: **C**, underside view; **D**, apertural view. **E–F**, *Biomphalaria pfeifferi*: **E**, underside view; **F**, apertural view. **G–H**, *Biomphalaria glabrata*: **G**, underside view; **H**, apertural view.

Planorbella cf *trivolvis* (Say, 1819)
(Alien species) Fig. 3.17C & D

Characteristic features

Maximum shell height and diameter 7 mm and 24 mm respectively. Holdfast organ cup-shaped.

Distribution

A North American species only known from artificial waterbodies in Durban, where it was first discovered in the 1960s.

Bulinus spp.

Bulinus is a large, variable and widespread genus. Its members are difficult to identify but are separable into four species-groups, three of which occur in southern Africa. The shell is sinistral, usually helicoid, uniform brown in colour with a matt texture. Can be confused with *Physa acuta* (compare Figs 3.18B, C & 3.19C).

Bulinus africanus group
(Figs 3.1A–C)

Characteristic features

Distinguished by their globose shape, short spire, correspondingly large basal whorl, and truncate columella. Maximum height about 25 mm and width 13 mm. Two species, *B. africanus* and *B. globosus*, have been described from southern Africa and both have the ridge or fold on the ventral surface of the kidney (Fig. 3.18A) and which is diagnostic for the group. Figure 3.18C gives a ventral view of *B. africanus*, showing the pseudobranch and typically blunt footsole of the Planorbidae (compare with Fig. 3.19C).

Distribution

B. africanus (Krauss, 1848) (Fig. 3.18B) occurs widely across the highveld of South Africa except for the Free State and western half of Northwest province. It also occurs in the lowveld from Limpoopo southwards through KwaZulu–Natal (except the coastal plain between the Mozambique border and Lake Nhlabane) to the Transkei. The closely related *B. globosus* (Morelet, 1866) is limited to the Mpumalanga lowveld southwards to the coastal strip of KwaZulu–Natal to Lake Nhlabane (lat. 28° 25' S). *Bulinus globosus* is also common in the Okavango River (but less so in the delta), Zimbabwe and Mozambique.

Remarks

Anatomy described by Mandahl-Barth (1958). Both species serve as intermediate hosts for the parasite *Schistosoma haematobium*, which

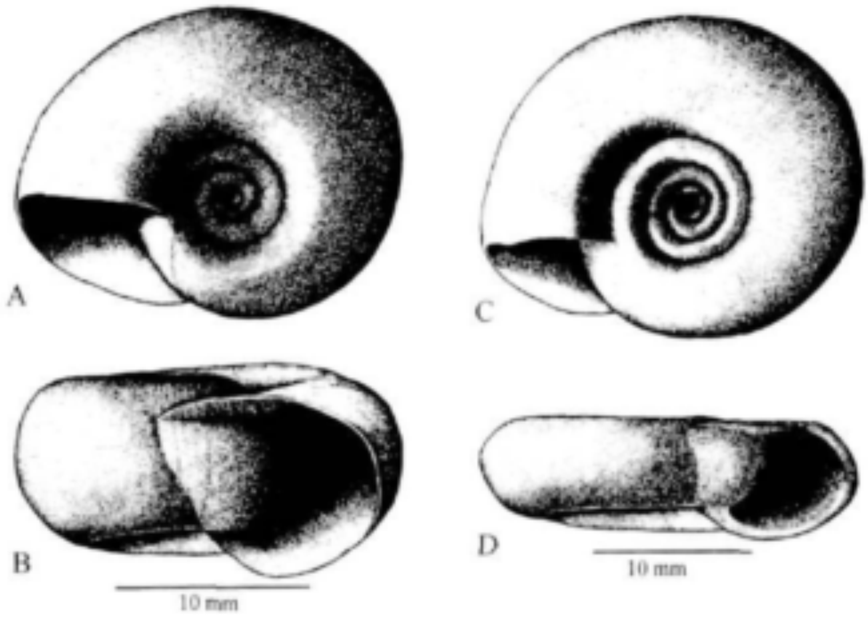

Fig. 3.17. Shells of Planorbidae. **A–B**, *Helisoma duryi*: **A**, underside view; **B**, apertural view. **C–D**, *Planorbella* cf. *trivolvis*: **C**, underside view; **D**, apertural view.

causes urinary bilharzia in man, and the cattle parasite, *S. mattheei*. For a map of the distribution of the *B. africanus* group, see de Kock & Wolmarans (1998).

Bulinus truncatus/tropicus group
Figs 3.18D–F

Shell globose but with a low to moderately developed spire, columella rounded, maximum height and width about 15 mm and 10 mm respectively. Three species are known from southern Africa but *B. tropicus* is the most widespread and common.

Bulinus tropicus (Krauss, 1848)
Fig. 3.18D

Characteristic features

Spire moderately high, sometimes appearing ribbed due to development of low, axial lamellae on the periostracum. Albino populations are sometimes found in which the soft parts are an orange/red colour.

Distribution

Common and widely distributed over the sub-continent but less so in the arid western parts of the Northern and Western Cape. For a map of the distribution of this species, see de Kock & Wolmarans (1998).

Remarks

Serves as the intermediate host for the conical fluke of cattle, *Calicophoron microbothrium*.

Bulinus depressus Haas, 1936
Fig. 3.18E

Characteristic features

A little known species with a typically flat (depressed) spire and prominent axial ribs. Aphally has been reported in this species.

Distribution

Recorded mostly from Northern, Northwest and Northern Cape provinces of South Africa, the Okavango River system, East Capriv wetlands (Namibia) and Lake Kariba. For a map of the distribution of this species see de Kock & Wolmarans (1998).

Remarks

Susceptible to infection by *S. haematobium* but is unlikely to play a meaningful role in bilharzia transmission.

Bulinus natalensis (Küster, 1841)
Fig. 3.18F

Characteristic features

Like *B. depressus*, this species has a flatter spire than *B. tropicus* but its shells are not ribbed. Aphallic specimens have been reported.

Distribution

Occurs predominantly in KwaZulu–Natal, especially along the eastern lowlands. For a map of the distribution of this species, see de Kock & Wolmarans (1998).

Bulinus forskalii group
Fig. 3.18G

Characteristic features

Differs from other bulinids in having an elongate, often ribbed shell with maximum height 17 mm and width 5 mm. Two species in southern Africa, *B. forskalii* (Ehrenberg, 1831) (Fig. 3.18G) and *B. scalaris* (Dunker, 1845) (not illustrated).

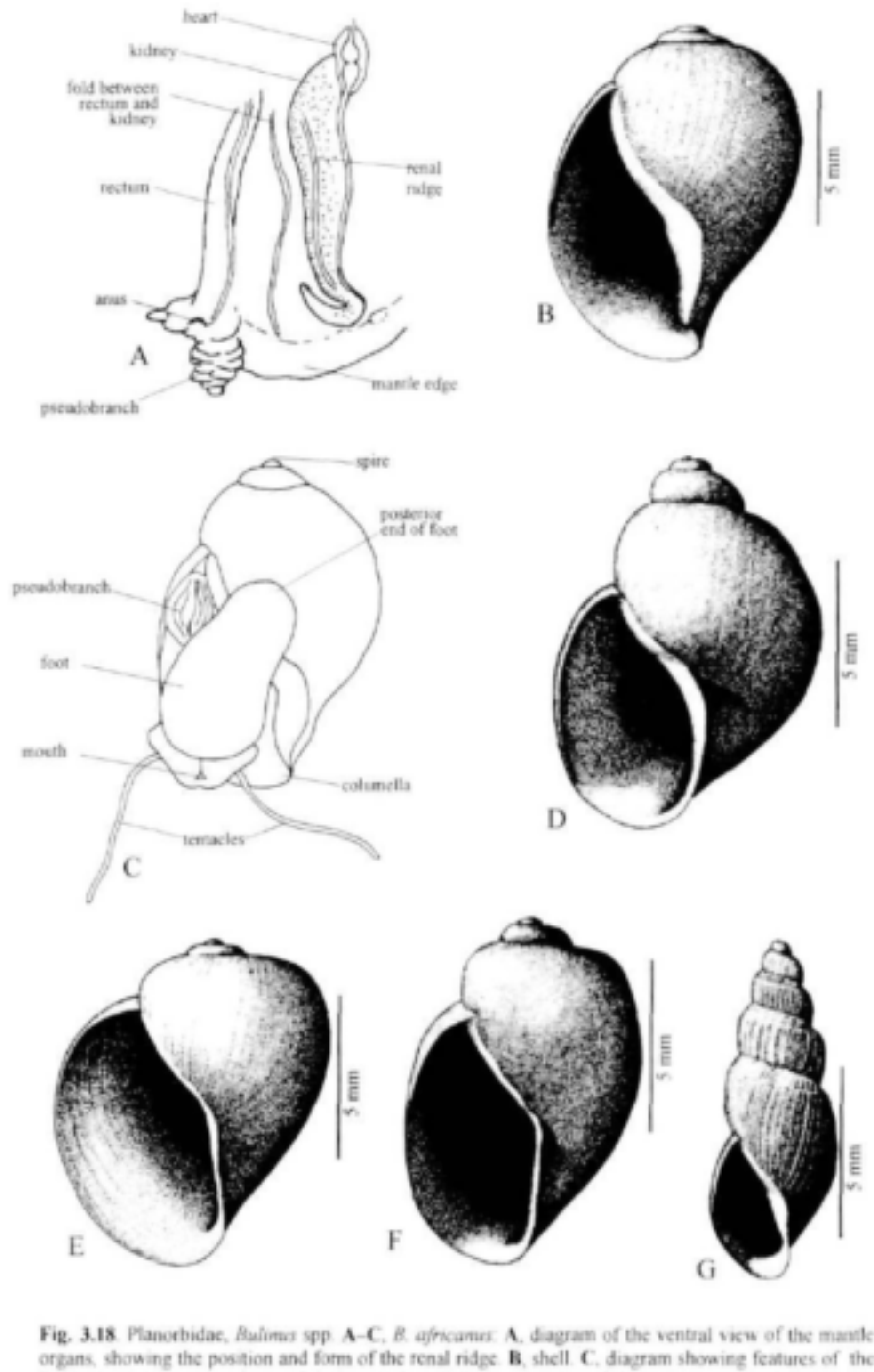

Fig. 3.18. Planorbidae, *Bulinus* spp. **A–C**, *B. africanus*: **A**, diagram of the ventral view of the mantle organs, showing the position and form of the renal ridge. **B**, shell. **C**, diagram showing features of the live animal and the position of the pseudobranch (note: anterior of the animal points downwards). **D–G**, shells of *Bulinus* spp. **D**, *B. tropicus*; **E**, *B. depressus*; **F**, *B. natalensis*; **G**, *B. forskalii* (A redrawn from Mandahl-Barth, 1958, Fig. 18A).

Distribution

Bulinus forskalii occurs widely over southern Africa except the arid western and central parts. *B. scalaris* occurs chiefly in Zimbabwe and the northern areas of Namibia and Botswana.

Remarks

Both species have remarkable powers of aestivation and are typical inhabitants of seasonal, rain-filled pools. *B. forskalii* serves as the intermediate host for the conical fluke *Gastrodiscus aegyptiacus*, a parasite of horses.

FAMILY **PHYSIDAE**

Figs 3.19A–C

Shell ovate, spire sharply pointed. Texture often glossy due to the absence of a periostracum in some genera and the mantle being reflected over the shell, or part of it, in others. Umbilicus closed. A Nearctic family with two species introduced into southern Africa, one belonging to the genus *Physa* and the other to *Aplexa*. *Physa* has an externally visible accessory gland on the preputium (preputial or accessory gland) while *Aplexa* does not. There is no pseudobranch. May be confused with *Bulinus* (see Figs. 3.18C & 3.19B). Physids move more rapidly than either lymnaeids or planorbids, have sharply-pointed tails and may often be seen to partially rotate their shells on their bodies.

Physa acuta Draparnaud, 1805

(Alien species) Fig. 3.19A & C

Characteristic features

Shell grows to a maximum height and width of 12 mm and 8 mm respectively and has a H/W ratio of 1.38–1.74. As shown in Fig. 3.19C, the mantle edges are only slightly reflected over shell.

Distribution

A North American species, which has become invasive in many river systems in South Africa, Zimbabwe and Namibia.

Remarks

It is tolerant of polluted waters where it may occur in large numbers, up to $3000/m^2$ (Brackenbury & Appleton 1993). *Physa acuta* was estimated to have spread upstream in the Liesbeek River, Cape Town, over several years at an average rate of 2.5 km/y (Appleton & Branch 1989). Large individuals may carry egg masses on their shells. For a map of the distribution of this species, see de Kock et al. (1989).

Aplexa marmorata (Guilding, 1828)
(Alien species) Fig. 3.19B

Characteristic features

An elongate shell measuring up to 15 x 8 mm and with a H/W (height/width) ratio of 1.74–2.16. A pale spiral band is visible in the shell adjacent to the suture. In living specimens the mantle edge is digitated and is reflected over most of the shell.

Distribution

Native to South America where it was redescribed in detail by Paraense (1986) as *Physa marmorata*. This species is spreading in South Africa where it usually colonizes lentic waterbodies (artificial and natural) and occasionally backwaters in rivers. Recorded only below 180 m altitude, mostly in KwaZulu–Natal but also from isolated localities in Mpumalanga and Limpopo.

Remarks

The presence of identical snails (*Aplexa waterloti*) in parts of West Africa and an old record (*Physa mosambiquensis*) from Mozambique suggest that *A. marmorata* may have been spread by Portuguese ships plying the slave trade between Africa and Brazil (Appleton et al. 1989).

CLASS BIVALVIA
SUBCLASS AUTOBRANCHIA
ORDER MYTILOIDA
FAMILY **MYTILIDAE**
Figs 3.20A & B

A largely marine family with one species, *Brachidontes virgiliae*, in coastal lakes and the lower reaches of rivers from the Western Cape to Mozambique. This mussel, previously known as *Musculus virgiliae*, is usually found in brackwater habitats, where it may form the major component of the macroinvertebrate community.

Brachidontes virgiliae (Barnard, 1964)
Figs 3.20A & B

Characteristic features

A small species, up to 30 mm long, with umbones close to the anterior end (subterminal) and well-developed denticles internally on the anterior shell margin. Colour olive green with reddish to black markings with a distinctly ribbed external sculpture. Usually found in clusters attached to reeds or stones and plants such as *Potamogeton pectinatus*. Can reach very high densities (see section on Reproduction: p. 53).

Distribution

Occurs in the lower reaches of rivers from the Western Cape to Mozambique.

Remarks

Thrives in brack water (salinities 3–5) but can tolerate a wide range of fluctuating salinities, up to about 34. In permanently saline habitats, *B. virgiliae* can be confused with two other small marine/estuarine mytilids, *Brachidontes semistriatus* (Krauss, 1848) (formerly called *B. variabilis* Krauss, 1848) and *Arcuatula capensis* (Krauss, 1848). Combinations of three shell characters shown by Davies (1980) to separate these three species are therefore given below.

Brachidontes semistriatus: terminal umbones, no prominent denticles on anterior internal valve margins, weak antero-posterior external riblets. Distributed from Port Elizabeth to Mozambique.

Brachidontes virgiliae: subterminal umbones, pronounced denticles on anterior internal valve margins, pronounced antero-posterior external riblets.

Arcuatula capensis: strongly subterminal umbones, no denticles on anterior internal valve margins, no antero-posterior external riblets. Distributed from Western Cape to Mozambique.

ORDER VENEROIDA
FAMILY **UNIONIDAE**
Figs 3.20C–J

Shells moderate to large, dark brown in colour, sometimes with zig-zag sculpture in postero-dorsal quadrant; umbones situated slightly anterior to the vertical mid-line; umbonal area usually eroded. Inner shell surface pearly and hinge teeth conspicuous; viviparous; eggs develop in chambers (marsupia) formed from either the outer or both gill demibranchs. Larvae are glochidia and are parasitic on fish (see section on Reproduction). Four species belonging to two genera, *Unio* and *Coelatura*, are found in southern Africa. The more familiar spelling of the latter with the diphthong *ae*, i.e. *Caelatura*, has been shown to be incorrect (Rosenberg et al. 1990).

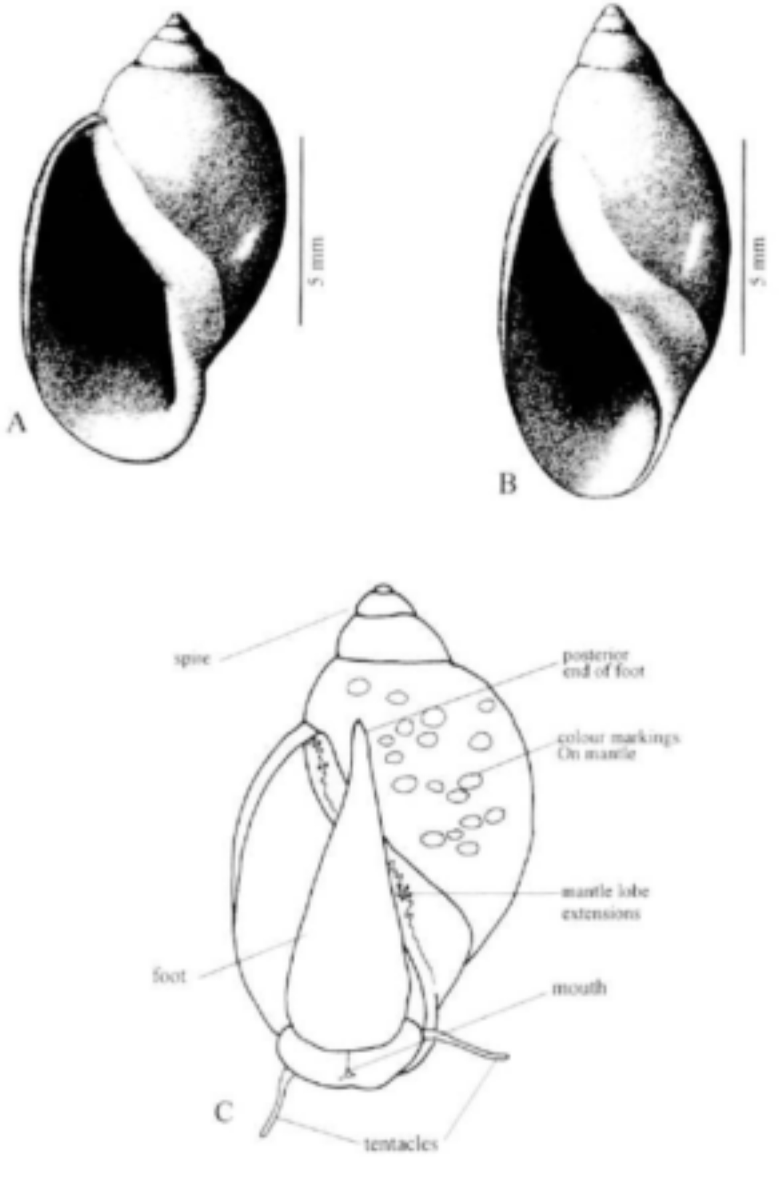

Fig. 3.19. Physidae. **A–B**, shells. **A**, *Physa acuta*; **B**, *Aplexa marmorata*. **C**, *Physa acuta* (with anterior pointing downwards), showing features of live animal (compare with *Bulinus africanus* in Fig 3.18C; note absence of a pseudobranch).

Unio caffer Krauss, 1848
Fig. 3.20C–E

Taxonomic note

Previously called *Cafferia caffra* (Krauss, 1848).

Characteristic features

Large specimens may reach 100 x 45 mm. The posterior end may be angular and variable in outline. Hinge with an ungrooved cardinal tooth (contrast Figs. 3.20 D and 3.20G), one anterior and two posterior lateral teeth. Juveniles have a chevron pattern of sculpture over the whole shell (Fig. 3.20E). Only the outer gill demibranch is marsupial. Glochidia with a hook on each valve.

Distribution

Widely distributed across southern Africa and endemic to the region, where it occurs in seasonal as well as perennial rivers, but is known from dams and small lakes as well. Has become rare in the south-western Cape where it can no longer be found in rivers such as the Berg, Breede and Kruis (J.A. Day pers. comm.).

Remarks

Tolerant of brackish water, up to salinities of 3. Baroque pearls have occasionally been found beneath the shell's nacreous inner layer.

Coelatura spp.

Three species of *Coelatura* are found in southern Africa but their distributions are not well known. Shell shape and details of hinge and sculpture may vary between adjacent river systems. Cardinal tooth with several grooves (contrast Figs 3.20 D and 3.20G). Juveniles with a chevron pattern of sculpture over the whole shell but adults retain only a few chevrons on the posterior half of the shell. Both gill demibranchs are marsupial. Glochidia without hooks (see *Unio*).

Coelatura kunenensis (Mousson, 1887)
Fig. 3.20F–H

Characteristic features

As with most coelaturae, it is a variable species. Shells from the Kunene and Okavango systems differ significantly in terms of their L/H ratios, those from the Okavango being higher than those from the Kunene (Appleton 1979). In addition, specimens from the Kunene River are typically dark brown whereas those from the Okavango may be paler and larger, and their chevron sculpture may persist to at least half adult size (Fig. 3.20H). Grows to 49 x 33 x 23 mm.

Distribution

Occurs in the Kunene, Okavango, upper Zambezi and Kafue River systems as well as the Ekuma floodplain and Etosha Pan in Namibia.

Coelatura mossambicensis (Martens, 1860)
Fig. 3.20I

Characteristic features

Grows to 50 x 30 x 20 mm. This species is relatively longer and more compressed than *C. kunenensis*. It resembles the next species, *C. framesi*.

Distribution

Found in Lake Kariba and the lower Zambesi River to central Mozambique. It also occurs in southern Malawi and eastwards-flowing rivers in Zimbabwe.

Remarks

Kenmuir (1980) gives useful data on the reproduction and ecology of *C. mossambicensis*.

Coelatura framesi (Connolly, 1925)
Fig. 3.20J

Characteristic features

Similar to the preceding but is generally longer relative to height, more slender and has more pronounced sculpture.

Distribution

Found to the south of the previous species' range, i.e. in the eastwards-flowing rivers of Mpumalanga and Limpopo and the Pongolo River flood-plain in north-eastern KwaZulu–Natal where it is common.

Remarks

May be synonymous with *C. mossambicensis*.

FAMILY **MUTELIDAE**
Figs 3.21 A–F

Medium to large-sized mussels with shells generally similar in external appearance to the Unionidae but lacking hinge teeth and sculpture. Central area of valves usually smooth but posterior area (and sometimes the anterior end as well) are rougher due to protruding growth lines. Umbones situated slightly anterior to the vertical mid-line, umbonal area often eroded, particularly in older specimens. Only the inner gill demibranch is modified to form brood chambers and the larvae are ectoparasitic on fish. Heavy infestations can kill the host fish. Four species belonging to three genera, *Aspatharia, Chambardia* and *Mutela*, occur in southern Africa. *Aspatharia* and *Chambardia* characteristically have a small triangular lunule at the posterior end of the hinge plate (arrowed in Fig. 3.21C). Valuable information on the reproduction and ecology of *C. wahlbergi* and *M. zambesiensis* is given by Kenmuir (1980).

Aspatharia pfeifferiana (Bernardi, 1860)
Fig. 3.21A

Characteristic features

Grows to about 85 x 37 mm.

Distribution

An apparently uncommon species, which is known only from the Kunene, Okavango and upper Zambesi rivers. It has not been found in the Okavango delta.

Chambardia wahlbergi (Krauss, 1848)
Fig. 3.21B & C

Taxonomic note

Until recently this species was known as *Spathopsis wahlbergi* (Krauss, 1848).

Characteristic features

This is the largest fresh water mussel in southern Africa, measuring up to 122 x 54 mm. Interior surface of valves often pinkish. Marsupia on inner pair of gill demibranchs only.

Distribution

Widely distributed from the Kunene River in the west to the eastward-flowing rivers of the highveld and KwaZulu–Natal north of 28° 30' S. Not known from the Okavango system.

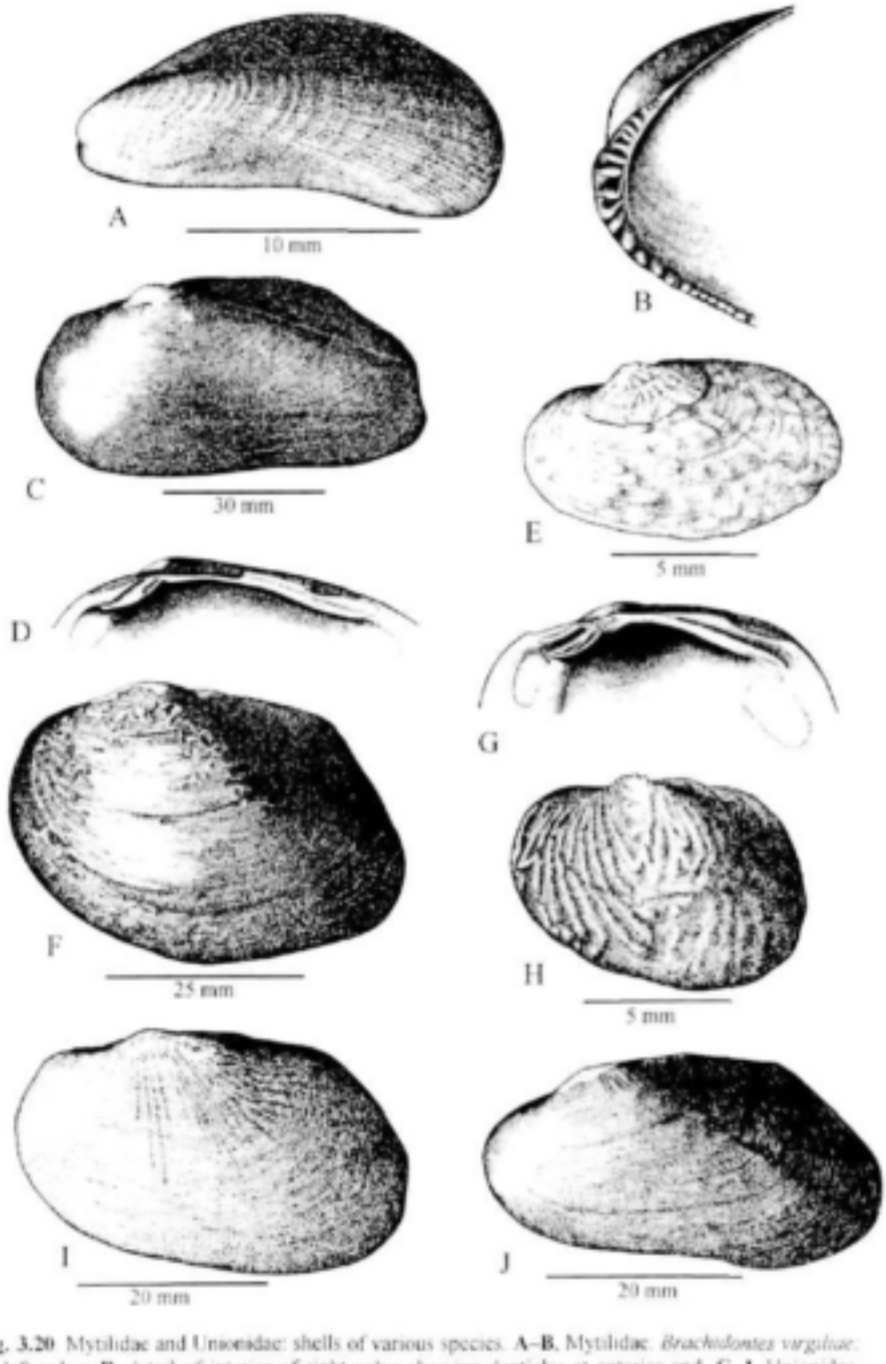

Fig. 3.20 Mytilidae and Unionidae: shells of various species. **A–B**, Mytilidae: *Brachidontes virgiliae*: **A**, left valve; **B**, detail of interior of right valve showing denticles at anterior end. **C–J**, Unionidae: **C–E**, *Unio caffer*: **C**, left valve of adult; **D**, detail of ligament and hinge teeth in right valve of adult; **E**, left valve of juvenile showing pattern of sculpture. **F–H**, *Coelatura kunenensis*: **F**, left valve of adult; **G**, detail of ligament and hinge in right valve of adult; **H**, left valve of juvenile showing sculpture. **I**, *Coelatura mossambicensis*, left valve. **J**, *C. framesi* (left valve).

Remarks

As in *U. caffer*, baroque pearls have been found in this species.

Chambardia petersi (Martens, 1860)
Fig. 3.21D

Characteristic features

Individuals small, rather elongate, measuring up to 72 x 30 mm and with the dorsal and ventral margins nearly parallel. Growth lines are finer than in the preceding species.

Distribution

Limited to the lower Zambezi River and the eastward-flowing rivers of Zimbabwe, Mozambique and Limpopo.

Mutela zambesiensis Mandahl-Barth, 1988
Fig. 3.21E & F

Characteristic features

A markedly elongate shell, usually brown/green in colour, particularly in young specimens where the colouration is often iridescent. May reach a length of over 110 mm. Larvae develop in brood sacs in inner pair of demibranchs only.

Distribution

A southern African species described recently from the Zambesi River and eastern Caprivi.

Remarks

Mutela is also common in the Kunene, Okavango and upper Zambezi rivers and rare in Mozambique and the Mpumalanga lowveld. Specimens from these two areas were previously identified as *M. dubia* (Gmelin, 1791) and *M. rostrata* (Rang, 1835) by Appleton (1979) and Connolly (1939) respectively. Since *M. zambesiensis* shares features with both these West African species, it seems preferable to use this name for all southern African specimens.

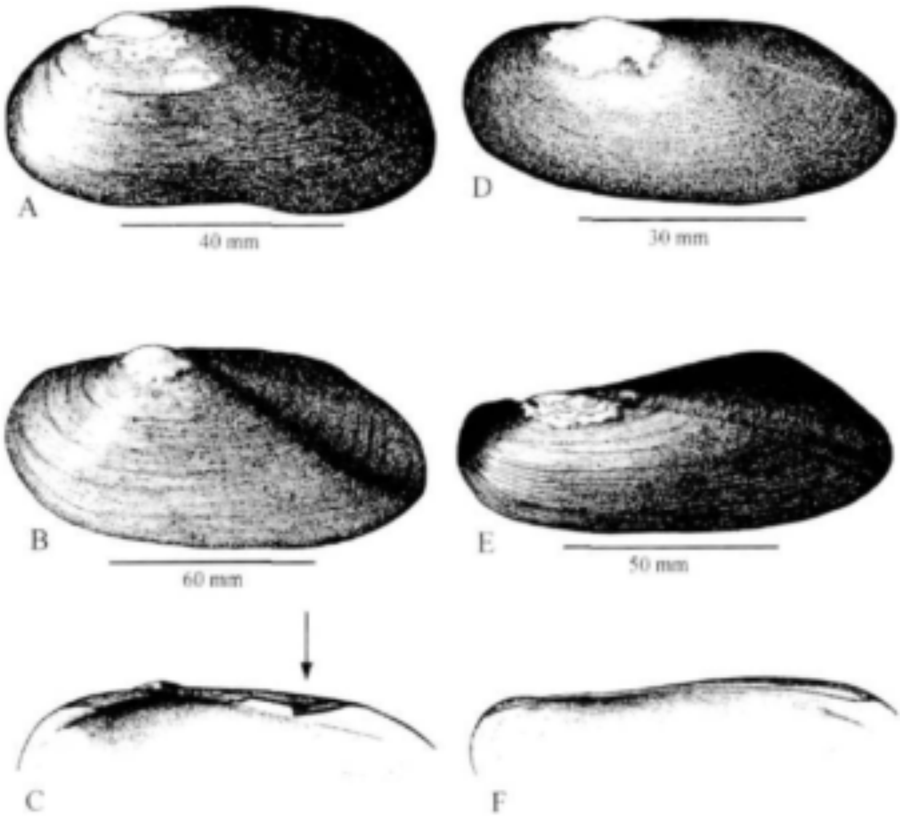

Fig. 3.21. Mutelidae: shells of various species: **A**, *Aspatharia pfeifferiana*, left valve. **B-C**, *Chambardia wahlbergi*: **B**, left valve; **C**, detail of hinge of right valve, note absence of teeth and presence of a lunule at the posterior end of the hinge plate. **D**, *C. petersi*, left valve. **E-F**, *Mutela zambesiensis*: **E**, left valve; **F**, detail of hinge of right valve (note absence of teeth).

FAMILY **ETHERIIDAE**

Fig. 3.22A & B

River oysters are found entirely within the tropics of Africa, Madagascar, India and South America. One species, *Etheria elliptica*, occurs in Africa and Madagascar. Shell inequivalve, irregular in shape with the lower valve longer than the upper. Hinge without teeth. The foot is typically lost in the adult. The anatomy of *E. elliptica* was described in detail by Yonge (1962).

Etheria elliptica Lamarck, 1807
Figs 3.22 A & B

Characteristic features

Unmistakable. The valves vary considerably in shape, but the upper is usually concave internally and the lower flattened. They may reach 120 x 82 mm.

Distribution

Known only from the lower reaches of the Kunene River, which represents the southernmost locality for the species in Africa.

Remarks

River oysters live, often in large numbers, with their lower valves cemented to submerged rocks in fast-flowing, turbulent stretches of rivers such as rapids. Normally they occur well below the surface, even during the dry season, and are thus seldom seen. This southernmost habitat of *E. elliptica* will be threatened by the construction of the proposed dam on the Kunene River. *Etheria* is eaten by people in several central African countries and its shells used as a source of lime.

FAMILY **CORBICULIDAE**
Figs 3.22C–E

Small triangular bivalves with solid, porcellaneous shells bearing a sculpture of strong concentric ribs. Hinge strongly developed with two or three radially arranged cardinal teeth and long, crenellated lateral teeth in both valves. Viviparous. Two species occur in southern Africa. *C. fluminalis* is widespread and often abundant, whereas the other species, *C. astartina*, is less common and seems restricted to the eastern half of the subcontinent.

Corbicula fluminalis (Müller, 1774)
Figs 3.22C & D

Characteristic features

Colour shiny brown or yellow to olive green with interior usually purple. Dark rays from umbo to margin are often present, particularly in juveniles.

Distribution

Widespread in rivers, lakes and dams across southern Africa except for the arid western parts. Occurs in large numbers in both flowing and standing waters.

Remarks

Previously considered an African species, *C. africana*, this mussel is now thought to be conspecific with *C. fluminalis* from Asia (Mandahl-Barth 1988).

Corbicula astartina Martens, 1860
Fig. 3.22E

Characteristic features

This species was considered a pale form of *C. fluminalis*, but is larger, longer, more strongly ribbed and uniformly yellow with a white interior. Its hinge teeth are more slender than those of *C. fluminalis*. It is recognized as a distinct but poorly known species.

Distribution

Reported sporadically from Zimbabwe, Mozambique, Mpumalanga, KwaZulu–Natal and Eastern Cape (Transkei) but is probably more widespread.

Remarks

May occur together with *C. fluminalis* but apparently much less abundant.

FAMILY **SPHAERIIDAE**
Figs 3.23A–G

Small bivalves with fragile shells, sometimes known as fingernail, pill or pea clams. Three genera, *Sphaerium*, *Pisidium* and *Eupera* occur in southern Africa but their systematics are in need of revision. When this has been done, several species will probably be seen to have a cosmopolitan distribution. Cardinal and lateral teeth are present, two cardinals in *Sphaerium* and *Pisidium* but only one in *Eupera*. Viviparous with embryos developing in broodsacs formed by gill filaments. Found in both flowing and standing waterbodies where they often occur in large numbers (see section on Habitat Preferences and Ecology: p. 59). Several species and genera may occur together.

Sphaerium capense (Krauss, 1848)
Figs 3.23A & B

Characteristic features

A small whitish shell, up to 9 mm long, rounded in shape with the umbones situated on the median vertical line. Valves inflated, anterior margin rounded. No sculpture except for growth lines.

Distribution

Known from the eastern lowlands of the sub-continent to the southern part of the Western Cape and also from the Okavango River system and Zimbabwe. Usually found in sand but may also occur in cryptic habitats such as crevices between the rhizomes of papyrus plant, *Cyperus papyrus*. Often found together with *Sphaerium incomitatum*.

Sphaerium incomitatum (Kuiper, 1966)

Fig. 3.23C

Characteristic features

Similar in size and colour to the preceding species but has a more oval-shaped shell with the umbones situated slightly posterior to the median vertical line. The anterior margin is more pointed. Valves less inflated than *S. capense*.

Distribution

Recorded sporadically from a wide area, viz. north-eastern KwaZulu–Natal, the Okavango River system and Zimbabwe, but probably more common.

Remarks

Korniushin (1995) considered that, on anatomical grounds, this species should belong in the Palearctic genus *Musculium*.

Pisidium

Eight species of *Pisidium* (Fig. 3.23D & E) have been reported from South Africa but they are difficult to separate and the genus is in need of revision. All are small whitish bivalves, up to 6 mm long but usually smaller. Umbones generally well posterior of the median vertical line. Apart from growth lines, sculpture has been reported for only two species, *P. costulosum*, which has concentric ribs on its shell, and *P. reticulatum*, which has a reticulate sculpture. *Pisidium pirothi* and *P. reticulatum* are the only species to have an externally visible ligament. A red/brown deposit is often present on the posterior and dorsal areas of *Pisidium* shells. Pisidia are known from most regions of the subcontinent and at least some species are very widely distributed, perhaps as a result of passive transport on insects and birds. Kuiper (1964, 1966) provided shell-based keys to South African and African species respectively. A modified version for southern African species is given on the following page.

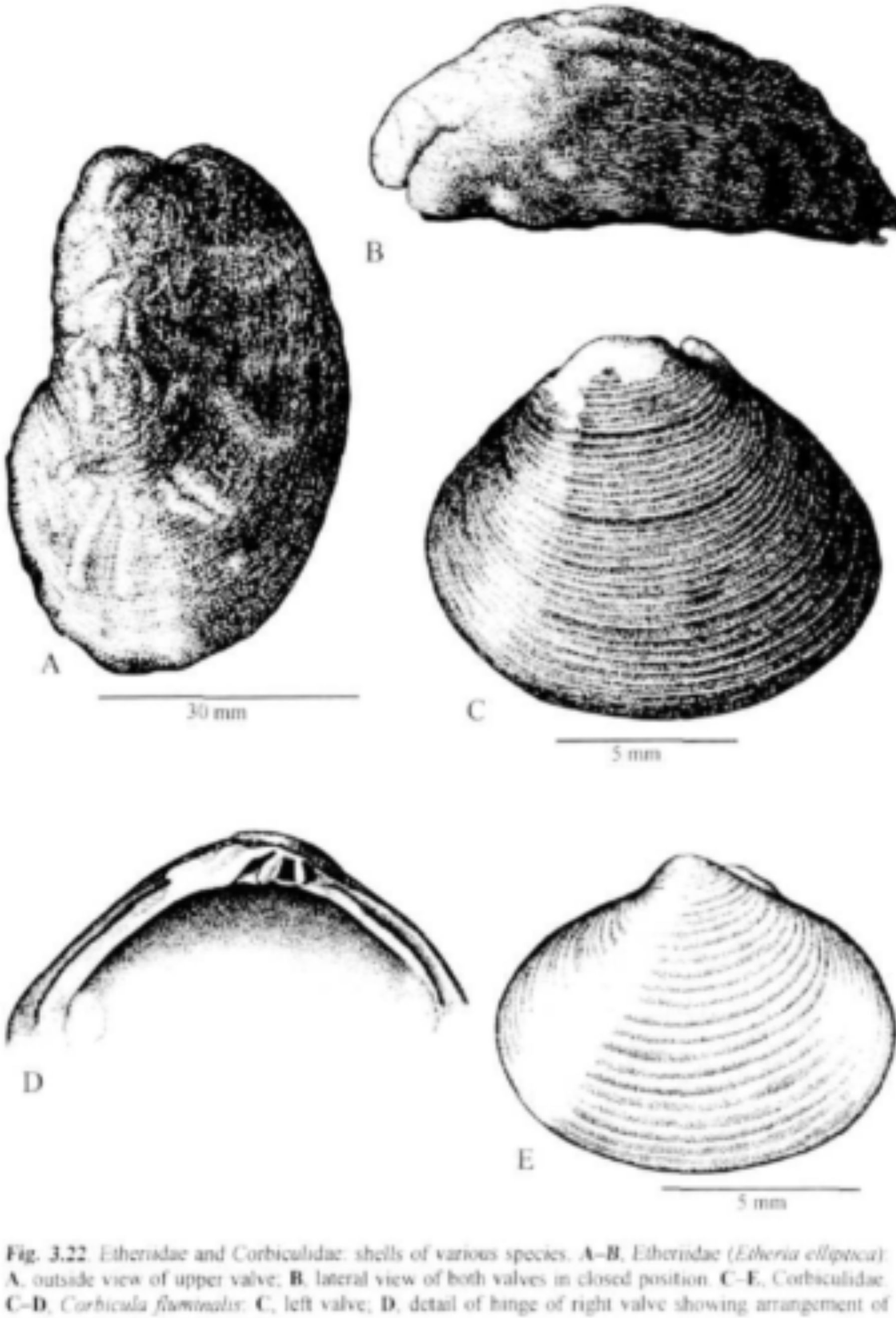

Fig. 3.22. Etheriidae and Corbiculidae: shells of various species. **A–B**, Etheriidae (*Etheria elliptica*): **A**, outside view of upper valve; **B**, lateral view of both valves in closed position. **C–E**, Corbiculidae. **C–D**, *Corbicula fluminalis*: **C**, left valve; **D**, detail of hinge of right valve showing arrangement of teeth. **E**, *C. astartina*, left valve.

KEY TO SPECIES OF *PISIDIUM* IN SOUTHERN AFRICA

1. Ligament projecting from dorsal margin, visible externally 2
– Ligament not projecting from dorsal margin, not visible externally 3

2. Sculpture of regular, fine striae at a density of 10 per 0.5 mm in middle of valve; umbones posterior to median vertical line; ligament-pit long and narrow; shell nearly transparent, inequilateral; length up to 4.75 mm .... *P. pirothi* Jickeli 1881
– Sculpture regular and reticulate; umbones submedian; length up to 3.5 mm .... *P. reticulatum* Kuiper, 1966

3. Umbones situated close to posterior end; shell outline oblong-oval, sculpture of thin, regular striations; grows to 4 mm in length ....*P. harrisoni* Kuiper, 1964
– Umbones median or submedian; shell outline ovate, subtrigonal or subpentagonal; equilateral or inequilateral; sculpture costulate (ribbed) or finely striate 4

4. Sculpture regularly costulate at 4–6 ribs per 0.5 mm in middle of valve; umbones submedian; grows to 3.5 mm in length ....*P. costulosum* Connolly, 1931
– Sculpture of regular, dense striae; umbones submedian; shell robust, outline subtrigonal; embryonic shell bounded by 3–6 distinctive striae grows to 4 mm in length ....*P. langleyanum* Melvill & Ponsonby, 1891
– Sculpture of dense, fine and regular striations; umbones submedian; shell thin and nearly transparent, outline ovate. ....*P. viridarium* Kuiper, 1956
– Sculpture irregularly striate, mostly very fine; shell outline ovate or subovate 5

5. Sculpture fine but irregular, shell equilateral, normally swollen, width being half height; posterior and anterior ends nearly equally rounded; ventral margin more curved than dorsal margin, which is nearly straight; umbones median; hinge very narrow; grows to 4.5 mm in length ....*P. ovampicum* Ancey, 1890
– Sculpture irregular, fine; shell normally swollen, anterior end more pointed than posterior end; inequilateral; dorsal margin, more curved than ventral margin; umbones submedian; central part of hinge plate rather broad; grows up to 6 mm in length ....*P. casertanum* (Poli, 1791)

Eupera spp.

Eupera species have angular, rhomboidal valves, with umbones situated anterior to the median vertical line. Hinge with a single, small cardinal tooth in each valve. Colour light brown with radiating darker flecks. May be attached by means of byssus threads to submerged plants such as *Ceratophyllum demersum*. Sometimes placed in a separate family, the Euperidae.

Eupera ferruginea (Krauss, 1848) has been collected from many parts of southern Africa and a second species, *E. parasitica* (Deshayes, 1854) (Figs 3.23 F & G), has also been reported from the region. The two are similar and difficult to separate but *Eupera ferruginea* has a greater height and shorter width than *E. parasitica* and has 14–16 growth lines per millimetre in the middle of the shell compared with 8–14 in the latter species. They may represent a single variable species. The genus *Eupera* is known from the eastern parts of southern Africa as far south as Durban (29° 48' S), also from the Okavango and Zambezi river systems, but distributions of the two described species are poorly known.

FAMILY **PSAMMOBIIDAE**

Figs 3.23 H & I

Shell weakly sculptured or smooth, ligament external and mounted on a narrow projection posterior to the umbo; hinge with small cardinal teeth only. Shell elongate, tapering posteriorly with valves gaping slightly when closed. Euryhaline, sand or mud-dwelling bivalves, which are locally abundant in the upper reaches of lagoons and estuaries along the east and southeast coast of South Africa.

Hiatula lunulata (Deshayes, 1855)

Fig. 3.23H & I

Characteristic features

Shell oblong, smooth with several violet rays sometimes visible externally hence the common name of 'sunset clam'; inner surface bluish. Periostracum thin and brown. Pallial sinus deep and rounded; shell grows to about 35 mm in length.

Distribution

May be very common in lagoons and estuaries of KwaZulu–Natal and the former Transkei where it tolerates salinities up to 30, although it is not known if it can breed throughout this salinity range (see section on Habitat Preferences and Ecology: pp. 59–60).

Remarks

Adults have long siphons, which allow them to burrow to depths of 200 mm or more. A second species, *H. clouei* Bertin, 1880, has a pointed pallial sinus and its periostracum is usually badly worn. It is less common than *H. lunulata* and only known from KwaZulu–Natal.

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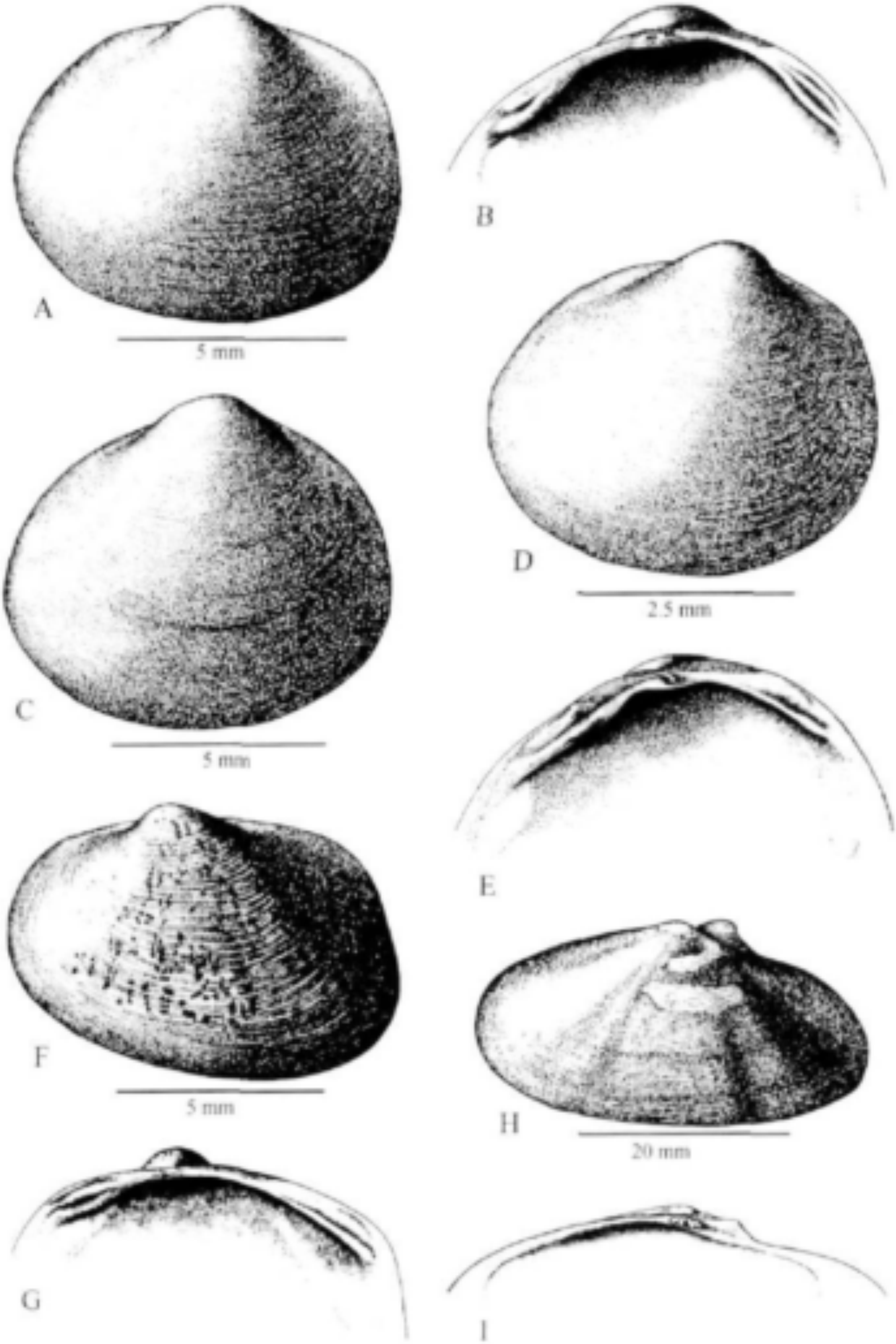

Fig. 3.23. Sphaeriidae (A–G) and Psammobiidae (H–I): shells of various species. **A–B**, *Sphaerium capense*: **A**, left valve; **B**, detail of hinge of right valve showing teeth. **C**, *S. incomitatum*: left valve. **D–E**, *Pisidium* spp.: **D**, left valve; **E**, detail of hinge of right valve showing teeth. **F–G**, *Eupera parasitica*: **F**, left valve; **G**, detail of hinge of right valve showing teeth. **H–I**, *Hiatula lunulata*: **H**, left valve; **I**, detail of hinge of right valve showing teeth.

CHECKLIST OF FRESH- AND BRACK- WATER MOLLUSCS FROM SOUTHERN AFRICA

Introductory note

The Gastropoda are arranged according to Brown (1994) and the Bivalvia according to Mandahl-Barth (1988). The list includes all indigenous and alien species from natural and semi-natural waters in southern Africa (excluding Malawi). Alien species—such as *Marisa cornuarietis*, *Pomacea* spp., and *Biomphalaria glabrata*—that are mentioned in the text but have not yet established populations in natural waters, have been excluded. It should also be noted that, since the many described species of *Burnupia* and *Ferrissia* need revision, their status as endemic or non-endemic species is not known. The proportion of species endemic to southern Africa is, nevertheless, remarkably low.

Class GASTROPODA
Subclass **Prosobranchia**

Family **Neritidae**
Neritina auriculata Lamarck, 1816
Neritina gagates Lamarck, 1822
Neritina natalensis Reeve, 1855
Neritina pulligera (Linnaeus, 1767)
Septaria borbonica (Bory de St Vincent, 1803)
Septaria tessellaria (Lamarck, 1816)

Family **Viviparidae**
Bellamya capillata (Frauenfeld, 1865)
Bellamya monardi (Haas, 1936)

Family **Ampullariidae**
Pila occidentalis (Mousson, 1887)
Lanistes ovum Peters, 1845

Family **Littorinidae**
Littoraria intermedia (Philippi, 1846)
Littoraria subvittata Reid, 1986

Family **Hydrobiidae**
Lobogenes michaelis Pilsbry & Bequaert, 1927

Family **Pomatiopsidae**
Tomichia alabastrina Morelet, 1889•
Tomachia cawstoni Connolly, 1939•
Tomichia differens Connolly, 1939•
Tomichia natalensis Connolly, 1939•
Tomichia rogersi (Connolly, 1929)•

• = alien species
• = species endemic to southern Africa

Family **Pomatiopsidae** (cont.)
Tomichia tristis (Morelet, 1889)•
Tomichia ventricosa (Reeve, 1842)•
Tomichia zwellendamensis (Küster, 1852-3)•

Family **Bithyniidae**
Gabiella kisalensis (Pilsbry & Bequaert, 1927)

Family **Assimineidae**
Assiminea ovata (Krauss, 1848)

Family **Thiariidae**
Thiara amarula (Linnaeus, 1758)
Tarebia granifera (Lamarck, 1816)*
Melanoides tuberculata (Müller, 1774)
Melanoides victoriae (Dohrn, 1865)
Cleopatra elata Dautzenberg & Germain, 1914
Cleopatra ferruginea (Lea, 1850)
Cleopatra nsendweensis Dupuis & Putzeys, 1903

Family **Potamididae**
Cerithidea decollata (Linnaeus, 1767)
Potamides conicus (de Blainville, 1826)
Terebralia palustris (Linnaeus, 1767)

Subclass **Pulmonata**

Family **Succineidae**
Oxyloma patentissima (Pfeiffer, 1853)

Family **Ellobiidae**
Auriculastra radiolata (Morelet, 1860)
Cassidula labrella (Deshayes, 1830)
Melampus semiaratus Connolly, 1912

Family **Lymnaeidae**
Lymnaea columella Say, 1817*
Lymnaea natalensis Krauss, 1848
Lymnaea truncatula (Müller, 1774)

Family **Ancylidae**
Burnupia brunnea Walker, 1924
Burnupia caffra (Krauss, 1848)
Burnupia capensis (Walker, 1912)
Burnupia farquhari (Walker, 1912)
Burnupia gordonensis (Melvill & Ponsonby, 1903)
Burnupia mooiensis (Walker, 1912)
Burnupia nana (Walker, 1912)
Burnupia obtusata Walker, 1926
Burnupia ponsonbyi Walker, 1924

* = alien species
• = species endemic to southern Africa

Family **Ancylidae** (cont.)

Burnupia stenochorias (Melvill & Ponsonby, 1903)
Burnupia transvaalensis (Craven, 1880)
Burnupia trapezoidea (Boettger, 1910)
Burnupia verreauxi (Bourguignat, 1853)
Burnupia vulcanus Walker, 1924
Ferrissia burnupi (Walker, 1912)
Ferrissia cawstoni Walker, 1924
Ferrissia clifdeni Connollyi, 1939
Ferrissia farquhari (Walker, 1924)
Ferrissia fontinalis (Walker, 1912)
Ferrissia junodi Connolly, 1925
Ferrissia lacustris Walker, 1924
Ferrissia natalensis Walker, 1924
Ferrissia victoriensis (Walker, 1912)
Ferrissia zambesiensis (Walker, 1912)
Ferrissia zambiensis Mandahl-Barth, 1968

Family **Planorbidae**

Afrogyrus coretus (de Blainville, 1826)
Ceratophallus natalensis (Krauss, 1848)
Gyraulus connollyi Brown & van Eeden, 1969•
Gyraulus costulatus (Krauss, 1848)
Lentorbis carringtoni (Azevedo et al., 1961)
Lentorbis junodi (Connolly, 1922)
Segmentorbis angustus (Jickeli, 1874)
Segmentorbis kanisaensis (Preston, 1914)
Segmentorbis planodiscus (Melvill & Ponsonby, 1897)•
Biomphalaria pfeifferi (Krauss, 1848)
Helisoma duryi (Wetherby, 1879)*
Planorbella cf. *trivolvis* (Say, 1819)*
Bulinus africanus (Krauss, 1848)
Bulinus angolensis (Morelet, 1866)
Bulinus depressus Haas, 1936
Bulinus forskalii (Ehrenberg, 1831)
Bulinus globosus (Morelet, 1866)
Bulinus natalensis (Küster, 1841)
Bulinus reticulatus Mandahl-Barth, 1954
Bulinus scalaris (Dunker, 1845)
Bulinus tropicus (Krauss, 1848)

Family **Physidae**

Physa acuta Draparnaud, 1805*
Aplexa marmorata (Guilding, 1828)*

* = alien species
• = species endemic to southern Africa

Class BIVALVIA
Subclass **Autobranchia**

Family **Mytilidae**
Brachidontes virgiliae (Barnard, 1964)

Family **Unionidae**
Unio caffer Krauss, 1848[●]
Coelatura framesi (Connolly, 1925)[●]
Coelatura kunenensis (Mousson, 1887)
Coelatura mossambicensis (Martens, 1960)

Family **Mutelidae**
Aspatharia pfeifferiana (Bernardi, 1860)
Chambardia petersi (Martens, 1860)
Chambardia wahlbergi (Krauss, 1848)
Mutela zambesiensis Mandahl-Barth, 1988)[●]

Family **Etheriidae**
Etheria elliptica Lamarck, 1807

Family **Corbiculidae**
Corbicula astartina Martens, 1860
Corbicula fluminalis (Müller, 1774)

Family **Sphaeriidae**
Sphaerium capense (Krauss, 1848)
Sphaerium incomitatum (Kuiper, 1966)
Pisidium casertanum (Poli, 1791)
Pisidium costulosum Connolly, 1931
Pisidium harrisoni Kuiper, 1964[●]
Pisidium langleyanum Melvill & Ponsonby, 1891
Pisidium ovampicum Ancey, 1890
Pisidium pirothi Jickeli, 1881
Pisidium reticulatum Kuiper, 1966
Pisidium viridarium Kuiper, 1956
Eupera ferruginea (Krauss, 1848)
Eupera parasitica (Deshayes, 1854)

Family **Psammobiidae**
Hiatula clouei Bertin, 1880
Hiatula lunulata (Deshayes, 1855)

• = alien species
● = species endemic to southern Africa

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GLOSSARY OF TERMS

acetabula	(sing. acetabulum): in water mites, small knoblike or cuplike structures on or near the acetabular (= genital) plates; function unknown
acetabular plates	in water mites, ventral sclerites associated with the genital field and bearing genital acetabula (q.v.)
acuminate	tapering to a fine point
adnate	attached, usually by its whole length
adductor muscle	in bivalve molluscs, any of the muscles that pull the two valves together
aerobic	living in the presence of oxygen (sometimes, by implication, unable to live without oxygen)
aestivation	a state of inactivity during an unfavourable period (usually in summer)
alien	of species, those distributed intentionally or unintentionally by humans to areas outside of their native ranges
ambulacrum	in water mites, terminal appendages of the tarsi, usually con- sisting of two retractable claws
amphibious	able to live both in and out of water
anastomosing	cross-connecting
anoxic	lacking in oxygen
aperture	in gastropod molluscs, the opening of the shell
apertural view	in molluscs, a view of the shell as seen when the aperture is facing the viewer
apex	(pl. apices): tip
aphally	in snails, the condition in which the copulatory organ is reduced or absent
apical view	in molluscs, a view of a shell seen from above
arthroideal membrane	a membranous part of the integument covering a joint between sclerites
basal whorl	in gastropod molluscs, the largest and final whorl of a shell
body pores	in water mites, the small circular areas of thin integument
buccal mass	the mass of tissue around the mouth
byssus	in some bivalve molluscs (mussels), a tuft of fibres, secreted by the foot, that anchor the animal to the substrate
calcareous	chalky, being composed of calcium carbonate
cardinal tooth	in bivalve molluscs, one of the interlocking teeth in the middle of the hinge plate (q.v.)
cercaria	the infective free-living final larval stage of flukes (q.v.) like *Schistosoma* (which causes bilharzia) (cf. *miracidium*)
chela	the nipper-like terminal segments of the chelicerae (q.v.) of arachnids
chelate	nipper-like

chelicera	(pl. chelicerae): in arachnids, the most anterior of the appendages
cheliceral teeth	in spiders, the teeth on the anterior and posterior margins of the chelicerae
chevron	in spiders, the V-shaped pattern on the abdomen
cilium	(pl. cilia): minute motile hairlike organelles growing from a cell
clawlets	in water mites, claw-like subdivisions of the ambulacral claws
columella	in snails, the axis around which the shell grows
condyle tion	in water mites, the heavily-sclerotized point of articula- between the coxa and the rest of the leg
corneous	horny in appearance, composed largely of a protein-like substance called keratin
cosmopolitan	found throughout the world
costulate	being sculptured with fine ribs
coxa	(pl. coxae): the most proximal of the leg segments of arthropods — in water mites, large and flattened and adhering to the ventral surface of the body
crenellated	edged with small notches
cusp	an elevation on the working edge of a tooth
demibranch	in bivalve molluscs, one half of a series of folded gill filaments on either side of the body
denticle	a tiny tooth
depressed	flattened
dextral	of snails, those having the aperture of the shell on the observer's right hand side when the spire is pointing upwards (cf. *sinistral*)
discoid/al	shaped like a disc
dorsal shield	in water mites, one or two large dorsal sclerites
egg coccon	in spiders, a mass of eggs, covered with a layer of silk
emergent	of aquatic vegetation, rooted in water but with stem and leaves in the air
endemic	of species, native to, and restricted to, a particular geographical region
epiphytic	living on plants
euryhaline	able to live in a wide range of salinities
exoskeleton	(= cuticle = integument): the external chitinous covering of arthropods, usually hardened in places
eye capsule	in some water mites, the distinct sclerites that house the lateral eyes

fascioliasis	a disease of domestic stock and humans caused by liver flukes of the genus *Fasciola*
filter feeder	an animal that feeds by filtering minute particles out of the water
flagellum	in some gastropods, a long slender tube that forms part of the male reproductive system
fluke	a parasitic flatworm of the class Trematoda
foot	in molluscs, the flattened muscular part of the body used in locomotion
formalin	a solution of formaldehyde in water: used as both as a fixative and a preservative
gamete	a sex cell (egg or sperm)
genital field	in water mites, the entire genital area, often delineated by the acetabular plates, that includes the gonopore and the area covered by the acetabula (q.v.)
genital plates	in some water mites, paired movable sclerites that cover the gonopore
genitalia	reproductive organs, including external components
glandularium	(pl. glandularia): in water mites, tiny exoskeletal glands, each associated with a seta
globose	globe-shaped
gill filaments	in bivalve molluscs, the series of folded filaments running down either side of the body
gnathosoma	in water mites, the small anterior body region bearing the mouthparts
gnathosomal bay	in water mites, the U- or V-shaped area between the anterior coxae in which the gnathosoma (q.v.) lies
gonochoristic	of a species, having separate males and females (cf *hermaphrodite*)
gonopore	an external opening of the reproductive system
helicoid	of snail shells, spirally coiled
hermaphrodite	of a species, having individuals bearing both male and female gonads
hinge teeth	in bivalve molluscs, the interlocking projections on the inner dorsal surface of the hinge plate (q.v.)
hinge	in bivalve molluscs, the dorsal part of the shell where the valves meet and are held together by a ligament and interlocking teeth
hinge plate	in bivalve molluscs, the dorsal margin of the shell that bears the hinge teeth (q.v.)
holdfast organ	(=preputial organ): in *Helisoma* (Planorbidae: Mollusca), a large glandular structure, inside the preputium, that produces leverage when the penial complex is everted during copulation.
hypersaline	of water, being more saline than some other reference liquid

hyposaline	of water, being less saline than some other reference liquid
hypostome	(= rostrum): in water mites, a narrowed antero-ventral projection of the gnathosoma (q.v.)
indigenous	native-born: originating in the region under discussion
inequivalve	in bivalves, with the two shells unequal in size
inflated	expanded
instars	a stage of development between moults
invasive	of species, those that spread unaided
lamella	a sheet
lateral	pertaining to the side or flank of an animal
lateral teeth	in bivalve molluscs, the interlocking projections or teeth on either side of the hinge (q.v.)
ligament	in bivalve molluscs, the fibrous part of the hinge mechanism
limpet	a flattened, non-helical snail
Lugol's Iodine	a solution of 1g iodine crystals and 2 g potassium iodide in *100 ml* distilled water
lunule	a dark, slightly sunken or depressed mark
macrophyte	a large plant
mantle	in molluscs, that part of the skin that covers the organs enclosed within the visceral hump
mantle cavity	in molluscs, the space inside the shell and anterior to the visceral hump
marsupium	in certain bivalve molluscs, the brood pouch that develops on the gills
mating apophysis	in spiders, an enlarged part of the chelicera or the front leg in males
median eye	(= frontal organ): in some water mites, a single unpaired eye
miracidium	in flukes (q.v.), the early larval stage that infects molluscs (cf. *cercaria*)
molluscicide	a poison used to kill molluscs
morph	an organism of particular shape and form
morphology	the shape and form of an organism
muscle scars	in bivalve molluscs, the scars left by muscles attached to the inside of the shell
nacreous	like mother-of-pearl: in molluscs, the iridescent inside surface of some shells
Nearctic	a zoogeographical region comprising continental North America southwards to Mexico
nucleus	the central point from which growth lines radiate on an operculum (q.v.)

operculum	in prosobranch gastropods, a 'lid' that closes the aperture
osmoconformer	an organism in which the body fluid is of the same osmotic concentration as that of the surrounding medium (cf *osmoregulation*)
osmoregulation	the process whereby animals regulate the amount of water and of various ions in their body fluids and cells
ovate	more or less oval
oviparous	of females, those that lay eggs
ovoviparous	of females, those that retain developing eggs within their bodies until the embryos are ready to hatch
pallial	line in bivalve molluscs, the line on the inside of the shell marking the position of attachment of the mantle (q.v.)
palp	(= pedipalp): in arachnids, the second pair of appendages
parietal region	in gastropod molluscs, the inner wall of the aperture of the shell
parthenogenesis	the production of offspring from unfertilised eggs
patelliform	shaped like a limpet (q.v.)
pedicel	in spiders, the thin stalk that attaches the abdomen to the cephalothorax
pedipalp	see *palp*
periostracum	the thin outermost layer of the shells of molluscs
periphyton	the minute plants and animals that grow on submerged surfaces
piscivorous	feeding on fish
pneumatophore	of mangrove trees, roots that stick out of the mud
polyphagous	consuming many different types of food
porcellaneous	like porcelain
preputial organ	in some snails the cup- or foot-shaped holdfast organ used to adhere to the partner during copulation
pseudobranch	in molluscs, an accessory gill formed from the outfolding of the mantle
quadrant	section, quarter
radial	arranged like rays or radiating lines
radula	the 'tongue' of most molluscs: a horny strip containing numerous sharp, tiny teeth
Railliet-Henry's Fixative	1 litre is made up as follows: 6 g sodium chloride, 50 ml concentrated formalin, 20 ml glacial acetic acid, 930 ml distilled water
reflexed	(= reflected): folded over or backwards
reticulate	with a criss-cross or networked design
retromarginal teeth	in spiders, teeth on the posterior margin of the cheliceral groove

rhomboidal	shaped like a rhombus: a quadrilateral with only the opposite sides and angles equal
robust	stout, strong
sclerite	a hardened unit of the body wall of an arthropod
sclerotized	of the exoskeleton (q.v.), hardened and tanned
secondary copulatory organ	in spiders, the structure on the tarsus of the male palp used to store sperm before mating
segment	one of the primary divisions of the body of an arthropod
segmented	of a body, made up of repeated units
setae	a relatively long, flexible, bristle-like process
shoulder	in the shells of snails, the outline of the upper part of a whorl (q.v.) as seen in profile
silk gland	in spiders, an abdominal gland situated postero-ventrally, opening *via* a spinneret (q.v.) and producing silk
sinistral	of snails, those having the aperture of the shell on the observer's left hand side when the spire is pointing upwards (cf. *dextral*)
siphon	a tube that carries water into (or away from) the mantle cavity of molluscs
siphonal canal	in some snails, a notch in the basal lip of the aperture of that accommodates the siphon (q.v.)
spiderlings	young spiders between instars 2–4 (q.v.)
spire	in snails, the coil(s) of the shell above the basal whorl
striate	with fine streaks or lines or furrows
sub-	more-or-less
suture	in gastropods, the junction line between the whorls (q.v.) of a shell
sutural angle	in gastropods, the angle between the two whorls at the suture
tarsus	the most distal segment of the leg of an arachnid or insect
truncate	with the end seemingly cut off
tubercle	a small rounded protuberance
turbinate	shaped like a spinning-top
turbellarian	a flatworm of the phylum Platyhelminthes and class Turbellaria
turriform	elongate, shaped like a turret
umbilicus	in gastropod shells, a depression or space in the axial
base	of the shell
umbone	(pl. umbones) in bivalve molluscs, the portion of the shell above the hinge (q.v.)
uncate	of palps (q.v.) in water mites, a condition in which the ventral portion of the fourth segment is greatly expanded and the fifth segment folds against it

underside view	in molluscs, a view of the shell as seen from below
univalve	with a single valve or shell
valve	in bivalves, either of the two halves of the shell
venom duct	in spiders, the duct connecting the venom gland to an opening at the tip of the fang
venom gland	in spiders, a mass of cells that produces venom
venter	in water mites, the ventral surface
ventral shield	in water mites, the heavily sclerotized part(s) of the venter (q.v.) in which the coxae and genital field (q.v.) fuse to form one or more closely-fitting sclerites (q.v.)
viviparous	of females, nourishing the developing embryo within the body so that young are born alive
vulva	in spiders, the internal genital organs of the female
whorl	in gastropods, one complete turn of a spiral in the shell

GLOSSARY OF PLACE NAMES

NEW PROVINCIAL NAMES IN SOUTH AFRICA TOGETHER WITH ABBREVIATIONS USED IN THE TEXT

Eastern Cape (EC)	formerly the eastern part of the Cape Province.
Free State (FS)	formerly the Orange Free State.
Gauteng (GT)	*formerly the Pretoria/Witwatersrand/Vereeniging complex:* part of the Transvaal.
KwaZulu–Natal (KZN)	formerly Natal, which included Zululand.
Mpumalanga (MPL)	formerly the 'eastern Transvaal'.
Northern Cape (NC)	formerly the north-western part of the Cape Province.
Limpopo (LIM)	formerly the 'northern Transvaal' (prior to 1994) and 'Northern Province' (from 1994–2002).
North West (NW)	formerly the 'western Transvaal'.
Western Cape (WC)	formerly the 'western Cape'.

ABBREVIATIONS OF OTHER COUNTRIES IN SOUTHERN AFRICA

BOTS	Botswana
LES	Lesotho
MWI	Malawi
MOZ	Mozambique
NAM	Namibia
SWZ	Swaziland
ZAM	Zambia
ZIM	Zimbabwe

REGIONAL NAMES

Bushmanland	(= Boesmanland): The north-eastern parts of Namibia, the south-western parts of Botswana and the drier northern areas of the Northern Cape.
Cape	One of the four former provinces of South Africa now named as follows: the north-western part is now the Northern Cape; the south-western part is now the Western Cape ; the eastern part, together with the former Ciskei and Transkei (qv), is now the Eastern Cape.
Caprivi	The north-eastern 'panhandle' of Namibia.
Damaraland	The west-central region of Namibia.
Delgoa Bay	(= Baia de Maputo): large bay on east coast of Mozambique, site of Maputo Harbour
Drakensberg Mountains	The mountain range stretching from the northern regions of the Eastern Cape through the highlands of KwaZulu–Natal, Lesotho and the eastern Free State to Mpumalanga.
Greater Namaqualand	The south-eastern part of Namibia (also see 'Namaqualand').
Griqualand East	Border region between the Transkei (qv) and KwaZulu–Natal.
Griqualand West	Arid region from Bloemfontein (Free State) westwards into the North West Province.
Highveld	High-altitude inland plateau characterized by grassland vegetation. Predominantly in Gauteng and the Free State.
Kalahari	The desert region of the northern North West Province, southern Botswana and south-eastern Namibia.
Karoo	Arid central region of southern Africa characterized by low scrub vegetation and very little grass cover: predominantly in the southern Northern Cape, the western parts of the Eastern Cape, the former Transkei (qv) and the northern border of the Western Cape.
Kaokoveld (Kaokoland)	The arid north-western coastal regions of Namibia.
Kruger National Park	Large nature reserve in the north-eastern region of Mpumalanga on the Mozambique border.
Makatini Flats	Pongola River floodplain, north-east of Jozini, Maputaland (q.v.)

Maputaland	Coastal plain in the north eastern region of KwaZulu–Natal and southern Mozambique, bounded by the Lebombo Mountains in the west and the Indian Ocean in the east.
Namaland	The coastal areas of the central Namib (qv) in Namibia.
Namaqualand	Arid region along the western parts of the Northern Cape and continuing into Namibia, where it is known as Greater Nama-qualand (qv).
Namib Desert	The coastal desert of south-western Africa, extending roughly from the Orange River to Benguela in Angola.
Natal	One of the four former provinces of South Africa, which previously included the region variously known as Zululand and KwaZulu, now re-named KwaZulu–Natal.
Northern Province	One of the nine provinces of South Africa, now called 'Limpopo'.
Orange Free State	One of the four former provinces of South Africa, now known as the Free State.
Owamboland	(=Ovamboland): Northern region of Namibia.
Southern Cape	The southern coastal strip from Cape Agulhas in the west to Cape St Francis in the east.
Transkei	The region colloquially known as the Transkei is now part of the Eastern Cape Province, stretching from the Kei River to Port Edward on the KwaZulu–Natal border.
Transvaal	One of the four former provinces of South Africa: the northern part is now the Northern Province; the eastern part is now Mpumalanga; the southern part is now Gauteng and the western region is now part of the North West Province.
Zululand	in KwaZulu–Natal, the eastern coastal belt and adjacent interior from the Tugela River to the Mozambique border .

INDEX OF SCIENTIFIC AND COMMON NAMES