Chapter 1
A Brief History of the Lymnaeid Research

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Abstract The history of the lymnaeid research, from the mid-sixteenth century to the present, is briefly outlined, with a special emphasis on the development of the systematics of this family and the studies of parasitological significance of the pond snails. An index to the lymnaeid literature published during the last 120 years, which includes references to the most important publications, is also provided.

It appears that the lymnaeid gastropods (the pond snails is the English vernacular name for these animals) have been totally overlooked by the ancient and medieval naturalists. Aristotle, "the father of zoology," did not mention them, as well as many of the natural historians who lived prior to the mid-sixteenth century (Vinarski 2015). Ulisse Aldrovandi (1522–1605), a scientist of the Late Renaissance Italy, was, most probably, the first naturalist to mention a lymnaeid snail in his book, and to illustrate its shell. Aldrovandi (1606) published an image of the shell of *Lymnaea stagnalis* (Linnaeus, 1758), the great pond snail, and named it "Turbo levis item in stagnis degens" (i.e., "Turbo with smooth shell, living in stagnant waters"). Though one cannot find a scientific description of this mollusc in Aldrovandi's book, but in that epoch the very Latin name (non-binomial, i.e., consisting of more than two words) served as a brief account of an animal and contained some information helping to identify it. It is not surprising that the shell in Aldrovandi's picture

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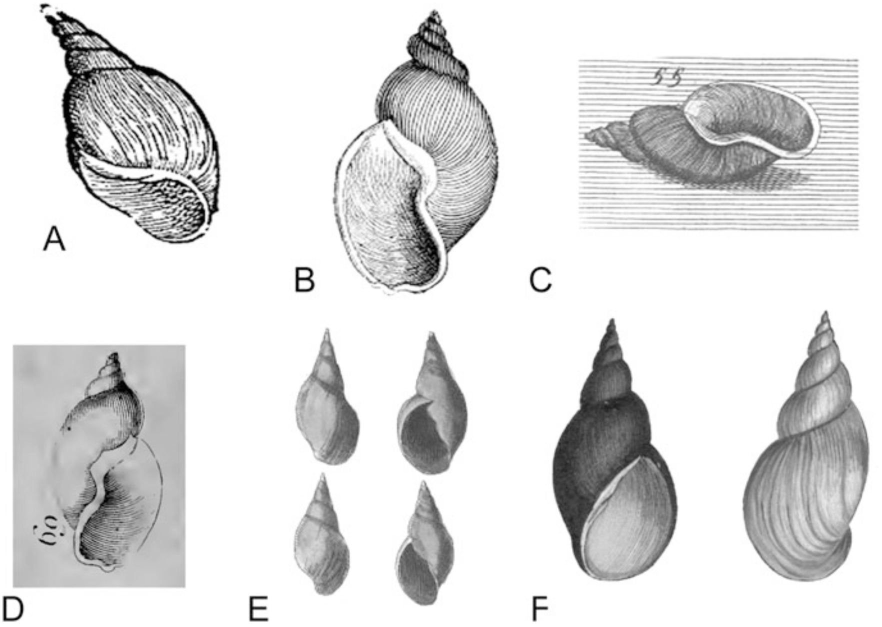

Fig. 1.1 Evolution of accuracy in illustrations of *Lymnaea stagnalis* shells made by naturalists of the seventeenth–eighteenth centuries. (**a**) Ulisse Aldrovandi (1606). (**b**) Martin Lister (1678). (**c**) Filippo Bonanni (1709). (**d**) Jacob Theodor Klein (1753). (**e**) Albert Seba (1758). (**f**) Johann Samuel Schröter (1779)

(Fig. 1.1) is sinistral (pond snails have normally dextral, or right-coiled, shells). The usual technique of engraving in the sixteenth and seventeenth centuries demanded that the plate must be a mirror image of the object to be illustrated. The printers usually were "not preparing a reversed engraving (on wood or copper), but carving the image [of a shell] as it appeared, which would produce a reversed image when printed" (Allmon 2007, p. 175).

Only 70 years later, a book authored by Martin Lister (1639–1712) was published in England, which contained much more detailed accounts on *L. stagnalis* and some other species of freshwater snails. Martin Lister was an English physician and naturalist, vice-president of the Royal Society from 1685 to 1686. Being a devoted conchologist, he wrote the first European treatises on molluscs (*Historiae Conchyliorum*, 1685; *Conchyliorum Bivalvium*, 1696). O.F. Müller (1774, p. xiii) called him "Conchyliologorum princeps» (head of conchologists), which is a clear analogy with Linnaeus' informal title "Princeps botanicorum."

In Lister's *Historiae animalium Angliae tres tractatus* (Lister 1678), one may find a detailed account of *L. stagnalis* that follows much higher standards of zoological descriptions compared with Aldrovandi's. This text contains not only the polynomial name (= short diagnosis) for this species, but also a relatively long two-page sketch of the great pond snail's bionomics. Lister provides a lengthy general description of its external morphology (including the pattern of mantle

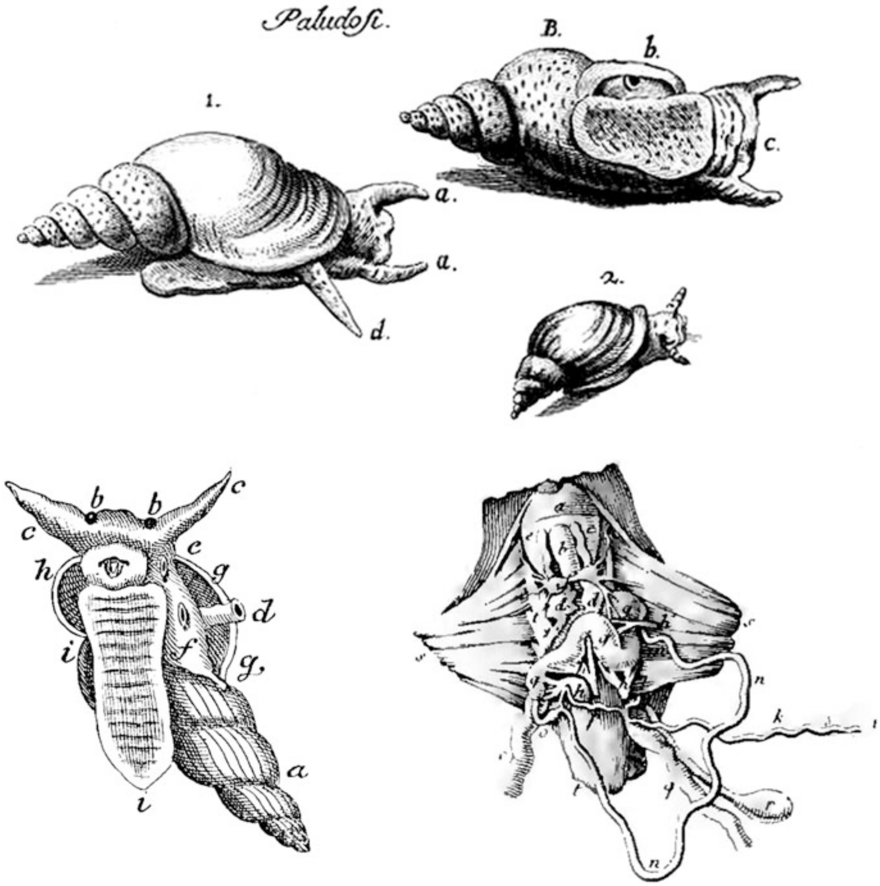

Fig. 1.2 Early illustrations demonstrating some details of the external and internal anatomy of *L. stagnalis*. Upper row – from Ginanni (1757), lower row left – after Swammerdam (1738), lower row right – after Cuvier (1817)

pigmentation), the shape of its excrements, the mode of copulation, the structure of egg-masses alongside a list of aquatic plants being its food. Some localities of *L. stagnalis* in England were also mentioned. Lister's species' account was almost 100 years ahead of its time. This high standard of publication of malacological data was not established until the end of the eighteenth/early nineteenth centuries, when comparable works of naturalists appeared (Müller 1774; Draparnaud 1805). Lister's account looks more detailed and inclusive than the account of the same species published a century later by Da Costa (1778)!

Later on, Lister (1695) published a very detailed report of the *L. stagnalis* internal structure, accompanied by engravings. Trained as a *medicus*, Lister was a brilliant anatomist aiming to dissect molluscs belonging to different taxa, both terrestrial and aquatic. Another perfect anatomist of the age, the Dutch Jan Swammerdam

(1637–1680), was also interested in freshwater molluscs (Fig. 1.2), and his study of the *L. stagnalis* anatomy was published posthumously in the author's prominent book *Bybel der natuure* (Swammerdam 1738). However, in both cases, the advance of anatomical research did not enhance the progress in taxonomy. Systematists of the seventeenth and eighteenth centuries typically did not use anatomical information in their works, and the classification of molluscs long remained purely conchological (Vinarski 2014).

In addition to *L. stagnalis*, Lister (1678) described two other lymnaeids, which may be tentatively identified with *Ampullaceana balthica* (Linnaeus, 1758) and *Radix auricularia* (Linnaeus, 1758). However, their descriptions are less detailed as compared with that of *L. stagnalis*.

The story of taxonomic investigation of the Lymnaeidae starts in 1753, when Jacob Theodor Klein separated lymnaeid snails into a taxon of their own—the genus *Auricula* with three species included (Klein 1753). Before Linnaeus' seminal work (Linnaeus 1758), Klein already explicitly used binomial nomenclature and introduced the first two-part name for the great pond snail—*Auricula stagnorum*. This name has a formal priority before the Linnaeus' *Helix stagnalis* but, being published before 1758, it is not available for taxonomic and nomenclatorial purposes.

Two other members of Klein's genus *Auricula* are more difficult to identify. His *Auricula pellucida*, is, perhaps, identical to *A. balthica*, whereas the third species, *Auricula exigua*, is of exotic origin ("Javana") and one is unable to identify it.

The basis for the subsequent taxonomic work on the family was laid within the 50 years after publication of the tenth edition of Linnaeus' *Systema Naturae*. During these years, several European naturalists and conchologists published descriptions of around 20 lymnaeid species, ten of which are accepted valid today (Box 1.1). It covered nearly one half of the overall diversity of this group in Western and Central Europe. The scope and quality of these descriptions ranged from short (1–2 phrases) and not illustrated diagnoses (Linnaeus 1758; Gmelin 1791) to more or less comprehensive accounts which included various data on species' morphology and ecology (Müller 1774; Draparnaud 1805). Toward the end of the eighteenth century, the minuteness of illustrations of the lymnaeid shells increased greatly and almost reached the modern standards (see Fig. 1.1).

All lymnaeid species described during the first 50 years of the post-Linnean taxonomy (i.e., since 1758) were placed within large and heterogeneous genera *Helix* and *Buccinum*, which included marine, terrestrial as well as true freshwater forms. Only in 1799 a new genus *Lymnaea* was erected by Lamarck, followed by other lymnaeid genera like *Galba* Schrank, 1803, *Radix* Montfort, 1810, and *Omphiscola* Rafinesque, 1819.

In the first half of the nineteenth century, the lymnaeid snails of the non-European (including exotic) countries were discovered. In North America, Thomas Say, "the father of American Conchology" (F.C. Baker 1911, p. 117), explored the Nearctic fauna of continental molluscs (Say 1817, 1821). He is the discoverer of many lymnaeid species accepted today as valid (*Bulimnea megasoma*, *Ladislavella catascopium*, *Pseudosuccinea columella*, and others). Travelers brought to Europe collections of freshwater molluscs of tropical countries. Lamarck (1822), Michelin

(1831), Krauss (1848), and some other workers contributed to the taxonomy of lymnaeids of India, East Asia, Africa. In Russia, Middendorff (1851) published a description of the pond snails of Siberia, a country whose invertebrate fauna was then almost unknown to zoologists.

This descriptive activity culminated in the mid-nineteenth century, when the first catalog of all known lymnaeid species appeared (Küster 1862). Küster's book was an annotated enumeration of almost 90 species from all continents, with descriptions and illustrations of their shells. This tradition was continued by illustrated catalogs authored by G.B. Sowerby II (1872) and Clessin (1882–1886). Westerlund (1885) compiled an annotated (but not illustrated) list of all species and varieties of lymnaeids occurring in the Palearctic region.

The volume of the family Lymnaeidae and its type genus, *Lymnaea*, had changed drastically during the last 100–150 years. In the nineteenth century, most workers treated Lymnaeidae as a family embracing almost all freshwater pulmonate snails, i.e. not only lymnaeids but also physids, planorbids, and some other groups (see, for example, Forbes and Hanley 1852–1853; Clessin 1882–1886; Locard 1893). Since the early twentieth century, the volume of the family became narrower. F.C. Baker (1911), Thiele (1931), Hubendick (1951) accepted it in an almost modern sense. Władysław Dybowski (1838–1910) who worked in Poland (then—a part of the Russian Empire) proposed the most radical system. This zoologist split the Lymnaeidae into three families of smaller volume: Limnaeidae, Lymnophysidae, and Amphipeplidae (W. Dybowski 1903). All his contemporaries, except Władysław's own brother Benedykt (B. Dybowski 1913), ignored these novelties.

The genus *Lymnaea* (alternatively spelled as *Limnaea*, *Limnaeus*, *Lymnaeus, Limnea*) had long served as a mega-genus to embrace almost all diversity of the pond snails, except of some conchologically peculiar forms like *Lanx* and *Myxas*. Typically, the genus *Lymnaea* s. lato had been divided into series of subdivisions (*Galba*, *Radix*, *Stagnicola*, and some others), which are ranked as separate genera in the present-day taxonomy. This "broad" concept of this genus dominated in the twentieth century (see review by Vinarski 2013), however most of the modern systematists arrange the family into numerous genera (Burch 1989; Ponder and Waterhouse 1997; Glöer 2002, 2019; Vinarski 2013; Aksenova et al. 2018; Vinarski et al. 2019, 2020).

Typically, the nineteenth century European malacologists accepted a relatively small number of lymnaeid species, albeit they used ad libitum the category of "varietas" (variety) in order to arrange the enormous intraspecific variation in lymnaeid shell size and proportions. The number of intraspecific entities delineated within some widespread and variable species might have been gargantuan; more than 80 "varieties" of *L. stagnalis* were proposed by taxonomists of the nineteenth and the first half of the twentieth century (Vinarski 2015). In most cases such varieties were based on relatively slight morphological deviations from the "type," i.e. in size, shell shape and proportions, shell surface coloration, etc. Not rarely, juvenile and aberrant individuals were used to establish a new "variety" or a new "morph." The extreme of such a splitting approach to taxonomy was observed in the nineteenth century France, where some malacologists created, on the basis of slight shell modifications, not "varieties" but "full" species. For example, Arnould Locard (1841–1904) delineated not less than 130 (sic!) species of Lymnaeidae in France alone (Locard 1893). One reason for it was that he considered the species category as arbitrary, non-objective. Locard wrote "L'espece malacologique est une notion purement arbitraire, indispensable aux naturalistes pour le besoin de la connaisance et de la classification des êtres" ("the malacological species is a purely arbitrary notion demanded by naturalists for the sake of knowledge and classification of [living] beings") (Locard 1893, p. 136).

It should be noted, however, that all abovementioned works were purely conchological and did not contain descriptions of anatomical characters. Until the early twentieth century, the shell characters remained virtually the only basis for genera and species delineation within the family.

At the same time, the anatomical studies on the Lymnaeidae, initiated in the late seventeenth century by Lister and Swammerdam, were continued by the great French zoologist and anatomist Georges Cuvier (1769–1832). In 1817, his "memoir" on morphology of *L. stagnalis* appeared (Cuvier 1817), in which the author described the external structure of the animal as well as the structure of its respiratory, digestive, nervous, and reproductive systems (see Fig. 1.2c). Some data on morphology of two other lymnaeid species were provided in the same paper. However, the anatomical studies had long remained detached from the taxonomic ones. Though the attempts to use the anatomical data for the purpose of lymnaeid classification were undertaken several times during the nineteenth century (van Beneden 1838; Troschel 1839; Klotz 1889), their impact on the practical taxonomy was almost negligible.

Let us, for example, consider a system of the Lymnaeidae proposed in 1905 by William H. Dall (1845–1927), a prominent American malacologist, in his monograph on Alaskan freshwater Mollusca (Dall 1905). This system was praised by F.C. Baker (1911, p. 118) as "the first attempt to place the classification of this group . . . on a modern basis." A closer look at Dall's system reveals that the diagnoses of genera and subgenera published by this author include only conchological characters, and Dall apparently did not dissect studied snails.

The system created by Frank C. Baker (1867–1942) himself constituted an important step toward the use of both conchological and anatomical data as the basis for classification of the pond snails. It was built by combining the traits of shell, radula, and genital anatomy (F.C. Baker 1911, 1915). In Europe, malacologists also started to describe the anatomical differences between lymnaeid species, with the strongest emphasis on reproductive organs, considered a very valuable source of taxonomic signal (Roszkowski 1914a, 1914b, 1925, 1929; J. Wagner 1927; de Larambergue 1928). Roszkowski (1914b) was among the first authors to apply anatomical data to clarification of the true taxonomic identity of some peculiar varieties and local races of lymnaeids described on the basis of shell characters. The jaw and radula structure were decided to be of rather low taxonomic value due mainly to its great intraspecific variation (Roszkowski 1929).

A new standard in lymnaeid taxonomy was set in the works of the Swedish malacologist Bengt Hubendick (1916–2012), perhaps the most influential researcher of the Lymnaeidae of the last century. Contrary to F.C. Baker's (1911, 1915) opinion, he believed that conchological differences are of lesser importance for lymnaeid taxonomy, and only qualitative structural distinctions in the reproductive anatomy may constitute a good basis for classification. During his extensive anatomical work, Hubendick (1951) could recognize only two *Bauplans* of the reproductive system within Lymnaeidae, and therefore sorted all pond snails into two genera: *Lymnaea* Lamarck, 1799 and *Lanx* Clessin, 1882. The latter genus is of North American distribution and includes lymnaeids with limpet-like shells and very peculiar anatomy (H.B. Baker 1925). The internal structure of *Lanx* is so unusual as compared to the rest of Lymnaeidae that this genus has often been placed in a separate family Lancidae Hannibal, 1914 (H.B. Baker 1925; Taylor and Sohl 1962; Starobogatov 1967; but see Walter 1969). All other species of lymnaeids from all continents proved to be too uniform in their anatomical structure even to delimit subgenera within the genus *Lymnaea* (Hubendick 1951). Hubendick demonstrated this amazing uniformity of the internal structures of the pond snails does not correspond to morphological diversity of their shells. Hubendick believed that conchological differences among taxa should be neglected if these are not accompanied by qualitative and stable differences in anatomical structures. He adhered to a very broad species concept and, as a result, he reduced a huge amount of 1150 species and varieties of lymnaeids, proposed prior to 1951, to a totality of nearly 40 species. Some of these species were conchologically polymorphic and characterized by very wide ranges. The quantitative anatomical differences between forms were almost ignored by Hubendick (1951).

However, as soon as 8 years later, Maria Jackiewicz (1920–2018) in Poland has shown that there are really more "good" species of pond snails even in the European waterbodies than it was accepted by Hubendick (Jackiewicz 1959). She reported clear anatomical differences among Eastern European species of the (sub-)genus *Stagnicola* Leach in Jeffreys, 1830 and described a new species, *Galba occulta* Jackiewicz, 1959. Since 1959, a new stage of description of novel species of pond snails has started. The classical approach to classification of the pond snails, based primarily on study of their shell characters and internal morphology, was accepted in the former USSR by Yaroslav I. Starobogatov (1932–2004) and Nikolay D. Kruglov (1939–2010). Working together, these authors developed an original system of the family and described several tens of new species as well as new supraspecific taxa (summarized in Kruglov 2005). In total, Kruglov and Starobogatov (1993a, 1993b) distinguished more than 140 species of Lymnaeidae in the fauna of Europe and Northern Asia, which far exceeded the species richness estimates made by the Western European malacologists. Their approach, however, met strong criticism and no malacologist working beyond the former USSR agreed with the lymnaeid classification proposed by Kruglov and Starobogatov (1993a, 1993b), though usually no serious analysis of their arguments was provided. For instance, Jackiewicz (1998, p. 3) stated that "opinions of Russian malacologists on the lymnaeid taxonomy <...> raised great doubts and <...> have not been taken into consideration." The reasons of these "great doubts" were, however, not explained by Jackiewicz. It is worth to note, however, that some species and genera delineated by Kruglov and

Starobogatov have recently received a molecular support (Vinarski et al. 2011, 2012, 2016; Aksenova et al. 2018).

An alternative morphology-based version of the Lymnaeidae system was published in 1997 by Ponder and Waterhouse (1997). Essentially, it was the last example of a "traditional" classification, since from 1997 onwards the DNA taxonomy starts to gain a foothold in the field (Bargues and Mas-Coma 1997; Remigio and Blair 1997a, 1997b; Bargues et al. 2001, 2003; Remigio 2002).

The limits of the strictly morphological approach to lymnaeid classification were obvious to everyone who is familiar with the high degree of shell and anatomical variability of these snails, both at the intra- and interspecific level. In the second half of the twentieth century, there were numerous attempts to expand the set of taxonomic methods and to apply new sources of information to classification of the family. None else than Kruglov and Starobogatov (1985) tried to use the method of crossing experiment for delineation of lymnaeid species. In doing so, they followed the "biological species concept" that proposes to delimit species on the basis of their reproductive isolation, which may be established experimentally. The authors attempted to demonstrate that *Lymnaea stagnalis* in Europe is a complex of several species, at least two of which, *L. stagnalis* s. str., and *L. fragilis* (Linnaeus, 1758), are reproductively isolated (Kruglov and Starobogatov 1985). The authors, however, acknowledged that this method has serious limitations when applied to hermaphroditic animals like aquatic pulmonate snails. The reason is that "their capacity for self-fertilization leads to difficulty in deciding whether the progeny is the result of self-fertilization of cross-fertilization between different forms" (Kruglov and Starobogatov 1985, p. 22). It can explain why the method has never gained much popularity among students of the lymnaeid snails.

Another approach, advocated by Kruglov (1986, 2005), was grounded on the so-called parasitological criterion. It was assumed that different species of parasitic trematodes are species-specific in their host choice, and each species of pond snails has its own specific circle of trematode larvae. If a larva infests a "wrong" host, it dies. Thus, observed differences in infestation by trematodes may be viewed as indirect evidence for taxonomic distinctness of two or more forms of lymnaeids (Kruglov 1986). However, recent parasitological and molecular studies showed that lymnaeid species serving as intermediate hosts of *Fasciola hepatica* are widely distributed across their phylogeny and basically, all clades contain species that have proven to be naturally or experimentally infected with the parasite (Correa et al. 2010).

A quite another approach to species delimitation used in the twentieth century zoological systematics was the biochemical one (Throckmorton 1968). In the 1960s–1980s, three basic types of experimental biochemical taxonomy techniques had been applied to freshwater Mollusca: chromatography, electrophoresis, and immunology (serology). Davis (1978) and Meier-Brook (1993) published reviews of these techniques in application to aquatic gastropods, with many examples of their practical usage for recognizing species. All these methods were directed toward identification of genotypic characters, including amino acid analysis of proteins, allowing thereby to characterize populations, species, or higher taxa of molluscs, and to assess relationships among them (Davis 1978). Allozyme electrophoresis was the most popular technique. Davis (1994, p. 3) recommended it as "an ideal tool for population genetics as applied to delineating species." A good illustration of this recommendation may be found in a population genetic study that was performed on populations of *Galba* species from several Neotropical countries. This study using starch gel electrophoresis analyzed populations from Venezuela, Cuba, Guadeloupe, Dominican Republic, and Bolivia as well as several *G. truncatula* samples collected from France, Portugal, and Morocco for comparison (Jabbour-Zahab et al. 1997). Multilocus enzyme electrophoresis was determined for 282 snails at 18 loci. Two genotypic groups could be differentiated by their multilocus genotypes (i) a Western genotypic group associating samples from Venezuela, Guadeloupe, Cuba, and Dominican Republic (*G. cubensis*) and (ii) an Eastern genotypic group associating samples from France, Portugal, and Morocco (*G. truncatula*). Surprisingly, the Northern Bolivian Altiplano populations formerly identified as *G. viator* did not present any divergence with the Portuguese sample and belong entirely to the Eastern genetic group (*G. truncatula*). These results showed that the lymnaeids coming from the Northern Bolivian Altiplano undoubtedly belong to the *G. truncatula* species (Jabbour-Zahab et al. 1997). In some countries, allozyme electrophoresis was exploited in the lymnaeid studies until quite recently (Mezhzherin et al. 2008) but today it is completely replaced by more advanced methods based on DNA sequencing.

Cytotaxonomy also had attracted many practitioners in the lymnaeid systematics of the last century (Perrot and Perrot 1938; Inaba 1969; Patterson and Burch 1978; Meier-Brook 1993) and was still in some use at the dawn of the new millennium (Garbar and Korniushin 2002; Garbar et al. 2004). Inaba (1969) attempted to reconstruct the phylogeny of the family based on cytotaxonomic and biogeographic evidence.

As it was mentioned above, since the last decade of the twentieth century, the molecular methods started to be actively used in the reviewed field. The current taxonomic work on the Lymnaeidae is based either on a strictly molecular approach (Bargues et al. 2006; Pfenninger et al. 2006; Puslednik et al. 2009; Correa et al., 2010) or on the "integrated" taxonomic scrutiny combining analysis of genetic, morphological, and zoogeographical information (Bargues et al. 2011; Correa et al. 2011; Schniebs et al. 2011, 2013; Vinarski et al. 2016; Campbell et al. 2017; Aksenova et al. 2018). The molecular methods also dominate in the studies of speciation and biogeography of lymnaeid snails (e.g., Albrecht et al. 2008; Cordellier and Pfenninger 2009; von Oheimb et al. 2011; Aksenova et al. 2018; Mahulu et al. 2019). The most recent advances in the fields of systematics and phylogeny of the family will be reviewed in subsequent chapters. Box 1.2 summarizes the most important works on the Lymnaeidae published over the last 120 years.

Of course, the lymnaeid studies of the last 50–70 years were not focused solely on taxonomy and phylogeny. The great pond snail, *L. stagnalis*, appeared to be a laboratory animal very suitable as a model object for studies in genetics, physiology, embryology, and some other experimental branches of biology (Freeman and Lundelius 1982; Meshcheryakov 1990; Fodor et al. 2020). Though this snail never reached a popularity in the laboratories comparable to that of the fruit fly or *Caenorhabditis elegans*, some important discoveries resulted from experiments with the great pond snail. A classical example is Alfred Sturtevant's (1891–1970) work, in which the phenomenon of "maternal inheritance" was discovered (Sturtevant 1923). Experimental works on the inheritance of sinistrality in lymnaeid snails, performed in England by Arthur Edwin Boycott (1877–1938) and his co-workers (Boycott and Diver 1923, 1927; Boycott et al. 1930), became a further substantial contribution to understanding of this phenomenon (reviewed briefly in Gurdon 2005).

Around a century ago, some lymnaeid species, whose shells were easy to obtain in large quantities, constituted an important object for studies in variability of animal populations. These works were significant for the advance of biometric methods and the progress of the "population thinking" in zoology. The students tried to reveal both the patterns of conchological variation and the factors that may govern them (Zhadin 1923; H. Wagner 1929; Boettger 1930; Peters 1938a; see review in Arthur 1982).

But the most important field of the applied lymnaeid studies is, surely, that aimed at revealing the complex relationships between trematode larvae and their mollusc hosts. The parasitological significance of the pond snails and their impact on public health in various countries are enormous and will be reviewed in detail in the second part of this book. Only a short historical introduction to these studies is worthy to provide here.

The history of studies of Trematoda parasitizing freshwater snails can be traced back to the late seventeenth century. Swammerdam (1738) discovered, described, and depicted some trematode larvae found inside bodies of aquatic Gastropoda. (The adult worms living inside organisms of humans and warm-blooded animals were known much earlier; see Grove 1990). The work on description of their diversity had continued during the next two centuries, but the life cycle of the trematodes and the role of snails as their reservoir hosts and vectors remained obscure until the end of the nineteenth century. For instance, Govert Bidloo (1649–1713), the Dutch physician, in 1688 expressed his opinion that the worms bred in moist earth then were swallowed together with their eggs in water by herbivorous animals such a sheep, stags, calves, and wild boars (Grove 1990). Fischer (1880, pp. 111–112) enlisted several trematode species whose larvae occur in molluscs, however all species included into his list use waterfowl and frogs, not humans or domestic animals, as their definitive hosts.

The liver fluke, *Fasciola hepatica*, became the first trematode in which the life cycle was understood. After a long series of investigations and fruitless attempts of various authors to work out the extremely complex development of this parasite, Rudolf Leuckart (1822–1898) in Germany and Algernon Thomas (1857–1937) in England, who had been working quite independently of each other, published papers (both appeared in October 1882; see Leuckart, 1882; Thomas, 1882) on this subject. Due to the efforts of these two students, the key role of the lymnaeid *Galba truncatula* (O.F. Müller, 1774) in the transmission of the parasite was firmly established. In the last century, this mollusc, also known as the dwarf pond snail (or the mud snail), became a focus of very intensive research in different countries of Europe (i.e., Patzer 1927; Zhadin and Pankratova 1931; Peters 1938b). Similar studies, involving other representatives of the genus *Galba*, were made in non-European countries, for example in Colombia (Brumpt et al. 1940).

Shortly after this discovery, many species of the Lymnaeidae were found to transmit other species of Trematoda of medical and veterinary importance (such as *Fasciola gigantica*, a cause of tropical fascioliasis, and *Fascioloides magna*, or the giant liver fluke). The family of pond snails is considered as one of the most significant from the point of view of public health, second only to planorbids (= Planorbidae s. lato, including bulinid snails) [Brown 1978; Bargues and Mas-Coma 2005; Vázquez et al. 2018].

Research on the role of molluscs as intermediate hosts of *Fasciola hepatica* has subsequently evolved as a result of successive outbreaks of animal or human distomatosis and the development of new analytical techniques. Until the 1980s, many species of Lymnaeidae were tested to determine their potential role as host snails in the parasite cycle (Kendall 1950; Berghen 1964; Boray, 1969, 1978; Busson et al. 1982; Kruglov 2005). Studies on several species of lymnaeids have also been carried out on various continents in order to know the characteristics of the environment in which they live, namely the life cycle of snails, the vegetation of their habitats, the associated fauna and the factors which act on snail ecology (Mehl 1932; Zhadin 1923; Roberts 1950; Chowaniec and Drozdz 1958; Stefanski 1959; Bednarz 1960; Over 1962, 1967; Erhardová-Kotrlá 1971; Pécheur 1974; de Kock et al. 1974; Smith 1981 for *G. truncatula*). The occurrence of an outbreak of human and animal distomatosis in 1968–1969 in central France (Dreyfuss et al. 2015b) prompted studies on the control of molluscs in order to determine whether methods of biological control (predators, competitors) had to be used alone or in combination with molluscicides which were already known at that time (Mage et al. 1989; Rondelaud et al. 2006). Additional research was carried out on histological sections of lymnaeids in order to determine the kinetics of the various larval stages which follow one another in the body of the snail (Rondelaud and Barthe 1982; Rondelaud et al. 2009) and the pathology that the parasite induces in the latter (Sindou et al. 1991). The development of modern analytical techniques (electrophoresis, molecular biology) since the 1990s has made it possible to determine whether the DNA or RNA of the parasite is present in the bodies of the snails studied (Caron et al. 2008; Kim et al. 2014; Alba et al. 2015, for example). The current development of PCR (polymerase-chain reaction) has changed the conventional methods (dissection, cercarial shedding) used by the authors to test for the presence of the parasite in molluscs (Caron et al. 2008). The PCR indicates whether miracidia have penetrated the lymnaeid, even if the larval forms have degenerated later in the body of the snail. However, its use alone does not permit the determination of whether a lymnaeid species in a given region is a potential intermediate host capable of transmitting the parasite or a non-target mollusc into which the miracidia have penetrated through a decoy effect.

Box 1.1 Enumeration of Lymnaeid Species Described During 1758–1803 (Only Species Accepted Today as Valid Are Included)

Original name (in brackets – combination accepted in current taxonomy)	Type locality	Authority
Buccinum glabrum (*Omphiscola glabra*)	Denmark	O.F. Müller (1774)
Buccinum glutinosum (*Myxas glutinosa*)	Denmark	O.F. Müller (1774)
Buccinum lagotis (*Ampullaceana lagotis*)	Germany	Schrank (1803)
Buccinum palustre (*Stagnicola palustris*)	Denmark	O.F. Müller (1774)
Buccinum peregrum (*Peregriana peregra*)	Denmark	O.F. Müller (1774)
Buccinum truncatulum (*Galba truncatula*)	Denmark	O.F. Müller (1774)
Helix auricularia (*Radix auricularia*)	Europe	Linnaeus (1758)
Helix balthica (*Ampullaceana balthica*)	Sweden	Linnaeus (1758)
Helix corvus (*Stagnicola corvus*)	Germany	Gmelin (1791)
Helix stagnalis (*Lymnaea stagnalis*)	Europe	Linnaeus (1758)

Box 1.2 A Short Index to the Lymnaeid Literature of the Last 120 Years

Field of study	References
Morphology	Boettger 1944; Jackiewicz 1954, 1993, 1998; Hubendick 1951, 1978; Walter 1969; Falniowski 1980; Meshcheryakov 1990; Kruglov 2005
Phylogeny and taxonomy	Dall 1905; FC Baker 1911; Thiele 1931; Hubendick 1951, 1978; Starobogatov 1967; Inaba 1969; Kruglov and Starobogatov 1993a, 1993b; Bargues and Mas-Coma 1997, 2005; Ponder and Waterhouse 1997; Jackiewicz 1993, 1998; Remigio 2002; Bargues et al. 2003; Garbar et al. 2004; Kruglov 2005; Puslednik et al. 2009; Correa et al. 2010; Dayrat et al. 2011; Vinarski 2013; Bouchet et al. 2017; Campbell et al. 2017; Aksenova et al. 2018; Saadi et al. 2020; Alda et al. 2021; Saito et al. 2021
Nomenclature and type series	Hubendick 1951; Sitnikova et al. 2012, 2014; Vinarski et al. 2013; Vinarski 2016; Eschner et al. 2020
Biogeography and ecology	Roszkowski 1928; Boycott 1936; Frömming 1956; Over 1967; Starobogatov 1970; Russell-Hunter 1964, 1978; McMahon 1983; Beriozkina and Starobogatov 1988; Banarescu 1990; Økland 1990; Dillon 2000; Stadnichenko 2006; Strong et al. 2008; Aksenova et al. 2018; Lounnas et al. 2017, 2018; Vinarski et al. 2019; Alda et al. 2021

(continued)

Fossil record	FC Baker 1911, Wenz 1923; Korobkov 1955; Wenz and Zilch 1959–1960; Pchelintsev and Korobkov 1960; Taktakishvili 1967; Gray 1988; Taylor 1988
Most important regional surveys	Yen 1939; Boettger 1944; Hubendick 1951; Brandt 1974; Burch 1989; Subba Rao 1989; Økland 1990; Kruglov and Starobogatov 1993a, 1993b; Brown 1994; Jackiewicz 1998; Glöer 2002, 2019; Gittenberger et al. 2004; Stadnichenko 2004; Kruglov 2005; Khokhutkin et al. 2009; Andreeva et al. 2010; Thompson 2011; Welter-Schultes 2012; Johnson et al. 2013; Pointier 2015; Piechocki and Wawrzyniak-Wydrowska 2016; Vinarski and Kantor 2016; Vinarski 2019; Pointier and Vàzquez 2020; Vinarski et al. 2020
Parasitological significance	Mozley 1957; Wright 1971; Brown 1978, 1994; Malek 1980; Mas-Coma and Bargues 1997; Kruglov 2005; Dreyfuss et al. 2015a; Pointier 2015; Caron et al. 2017; Vázquez et al. 2018; Celi-Erazo et al. 2020; Alba et al. 2019; Vázquez et al. 2019; Pereira et al. 2020

References

Aksenova OV, Bolotov IN, Gofarov MY et al (2018) Species richness, molecular taxonomy and biogeography of the radicine pond snails (Gastropoda: Lymnaeidae) in the Old World. Sci Rep-UK 8:11199. https://doi.org/10.1038/s41598-018-29451-1

Alba A, Vázquez AA, Hernández H et al (2015) A multiplex PCR for the detection of *Fasciola hepatica* in the intermediate snail host *Galba cubensis*. Vet Parasitol 211:195–200. https://doi.org/10.1016/j.vetpar.2015.05.012

Alba A, Vázquez AA, Sánchez J et al (2019) Patterns of distribution, populations genetics and ecological requirements of field-occurring resistant and susceptible *Pseudosuccinea columella* snails to *Fasciola hepatica* in Cuba. Sci Rep-UK 9:14359. https://doi.org/10.1038/s41598-019-50894-7

Albrecht C, Wolff C, Glöer P et al (2008) Concurrent evolution of ancient sister lakes and sister species: the freshwater gastropod genus *Radix* in lakes Ohrid and Prespa. Hydrobiologia 615: 157–167. https://doi.org/10.1007/978-1-4020-9582-5_11

Alda P, Lounnas M, Vázquez AA et al (2021) Systematics and geographical distribution of *Galba* species, a group of cryptic and worldwide freshwater snails. Molec Phyl Evol 157:107035. https://doi.org/10.1016/j.ympev.2020.107035

Aldrovandi U (1606) De reliquis animalibus exanguibus libri quatuor post mortem eius editi nempe de mollibvs, crvstaceis, testaceis et zoophytis. Bellagamba, Bologna. https://doi.org/10.5962/bhl.title.118781

Allmon WD (2007) The evolution of accuracy in natural history illustration: reversal of printed illustrations of snails and crabs in pre-Linnaean works suggests indifference to morphological details. Arch Nat Hist 34:174–191

Andreeva SI, Andreev NI, Vinarski MV (2010) Key to freshwater gastropods of Western Siberia (Mollusca: Gastropoda). V. 1. Gastropoda: Pulmonata. Fasc. 1. Families Acroloxidae and Lymnaeidae. The authors, Omsk. [in Russian]

Arthur W (1982) Control of shell shape in *Lymnaea stagnalis*. Heredity 49(2):153–161. https://doi.org/10.1038/hdy.1982.81

Baker FC (1911) The Lymnaeidae of North and Middle America. Special Publication of the Chicago Academy of Sciences 3:1–539. https://doi.org/10.5962/bhl.title.20500

Baker FC (1915) On the classification of the Lymnaeids. The Nautilus 29(2):20–24

Baker HB (1925) Anatomy of *Lanx*, a limpet-like Lymnaeid Mollusc. Proceedings of the Californian Academy of Sciences. Fourth Series 14(8):143–169

Banarescu P (1990) Zoogeography of fresh waters. Vol. 1. General distribution and dispersal of freshwater animals. AULA-Verlag, Wiesbaden

Bargues MD, Mas-Coma S (1997) Phylogenetic analysis of lymnaeid snails based on 18S rDNA sequences. Mol Biol Evol 14(5):569–577. https://doi.org/10.1093/oxfordjournals.molbev.a025794

Bargues MD, Mas-Coma S (2005) Reviewing lymnaeid vectors of fascioliasis by ribosomal DNA sequence analyses. J Helminthol 79:257–267. https://doi.org/10.1079/JOH2005297

Bargues MD, Vigo M, Horák P et al (2001) European Lymnaeidae (Mollusca: Gastropoda), intermediate hosts of trematodiases, based on nuclear ribosomal DNA ITS-2 sequences. Infect Genet Evol 1:87–107. https://doi.org/10.1016/S1567-1348(01)00019-3

Bargues MD, Horák P, Patzner RA et al (2003) Insights into relationships of Palearctic and Nearctic lymnaeids (Mollusca: Gastropoda) by rDNA ITS-2 sequencing and phylogeny of stagnicoline intermediate host species of *Fasciola hepatica*. Parasite 10:243–255. https://doi.org/10.1051/parasite/2003103243

Bargues MD, Artigas P, Jackiewicz M et al (2006) Ribosomal DNA ITS-1 sequence analysis of European stagnicoline Lymnaeidae (Gastropoda). Heldia 6(1–2):57–68

Bargues MD, Artigas P, Khoubbane M et al (2011) *Lymnaea schirazensis*, an overlooked snail distorting fascioliasis data: genotype, phenotype, ecology, worldwide spread, susceptibility, applicability. PLoS One 6:e24567. https://doi.org/10.1371/journal.pone.0024567

Bednarz S (1960) On the biology and ecology of *Galba truncatula* Müll. and cercariae of *Fasciola hepatica* L. in basin of the river Barycz. Acta Parasitologica Polonica 8:279–288

Berghen P (1964) Some Lymnaeidae as intermediate hosts of *Fasciola hepatica* in Belgium. Exp Parasitol 15:118–124

Beriozkina GV, Starobogatov YI (1988) Reproductive ecology and egg clusters of freshwater Pulmonata. Trudy Zoologicheskogo Instituta AN SSSR 174:1–306. [in Russian]

Boettger CR (1930) Die Standortsmodifikationen der Wasserschnecke *Radix auricularia* L. Helios 30:49–64

Boettger CR (1944) Basommatophora. Die Tierwelt der Nord- und Ostsee. Akademische Verlagsgesellschaft Becker and Erler Kom.-Ges., Leipzig 9(b2):241–478

Bonanni P (1709) Musaeum Kircherianum, sive Musæum a P. AthanasioKirchero in Collegio Romano Societatis Jesu jam pridem incoeptum, nuper restitutum, auctum, descriptum, & iconibus illustratum.Plachi, Roma

Boray JC (1969) Experimental fascioliasis in Australia. Adv Parasit 7:95–210

Boray JC (1978) The potential impact of exotic *Lymnaea spp.* on fascioliasis in Australasia. Vet Parasitol 4:127–141. https://doi.org/10.1016/0304-4017(78)90004-3

Bouchet P, Rocroi JP, Hausdorf B et al (2017) Revised classification, nomenclator and typification of gastropod and monoplacophoran families. Malacologia 61(1–2):1–526. https://doi.org/10.4002/040.061.0201

Boycott AE (1936) The habitats of fresh-water Mollusca in Britain. J Anim Ecol 5(1):116–186. https://doi.org/10.2307/1096

Boycott AE, Diver C (1923) On the inheritance of sinistrality in *Limnaea peregra*. P Roy Soc Lond B Bio 95:207–213. https://doi.org/10.1098/rspb.1923.0033

Boycott AE, Diver C (1927) The origin of an albino mutation in *Limnaea peregra*. Nature 119:9. https://doi.org/10.1038/119009a0

Boycott AE, Diver C, Garstang SL et al (1930) The inheritance of sinistrality in *Limnaea peregra* (Mollusca, Pulmonata). Philos T Roy Soc B 219:51–131

Brandt RAM (1974) The non-marine aquatic Mollusca of Thailand. Arch Molluskenkd 105:1–423

Brown DS (1978) Pulmonate molluscs as intermediate hosts for digenetic trematodes. In: Fretter V, Peake J (eds) Pulmonates, vol 2A. Academic Press, London, pp 287–333

Brown DS (1994) Freshwater snails of Africa and their medical importance. Taylor and Francis, London. https://doi.org/10.1201/9781482295184

Brumpt E, Velásquez J, Ucross H et al (1940) Découverte de l'hôte intermédiaire *Limnaea bogotensis* Pilsbry, de la grande douve *Fasciola hepatica*, en Colombie. Ann Parasit Hum Comp 17:563–579

Burch JB (1989) North American freshwater snails. Malacological Publications, Hamburg, MI

Busson P, Busson D, Rondelaud D et al (1982) Données expérimentales sur l'infestation des jeunes de cinq espèces de limnées par *Fasciola hepatica* L. Ann Parasit Hum Comp 57:555–563

Campbell DC, Clark SA, Lydeard C (2017) Phylogenetic analysis of the Lancinae (Gastropoda, Lymnaeidae) with a description of the U.S. federally endangered Banbury Springs lanx. Zookeys 663:107–132. https://doi.org/10.3897/zookeys.663.11320

Caron Y, Rondelaud D, Losson B (2008) The detection and quantification of a digenean infection in the snail host with special emphasis on *Fasciola sp*. Parasitol Res 103:735–744. https://doi.org/10.1007/s00436-008-1086-1

Caron Y, Celi-Erazo M, Hurtrez-Boussès S et al (2017) Is *Galba schirazensis* (Mollusca, Gastropoda) an intermediate host of *Fasciola hepatica* (Trematoda, Digenea) in Ecuador? Parasite 24:24. https://doi.org/10.1051/parasite/2017026

Celi-Erazo M, Alda P, Montenegro-Franco M et al (2020) Prevalence of *Fasciola hepatica* infection in *Galba cousini* and *Galba schirazensis* from an Andean region of Ecuador. Vet Parasitol Reg Stud Rep 20:100390. https://doi.org/10.1016/j.vprsr.2020.100390

Chowaniec W, Drozdz J (1958) Studies on biology and ecology of *Galba truncatula* and on larval forms of *Fasciola hepatica*. Wiad Parazytol 4:433–434. [in Polish]

Clessin S (1882–1886) Die Familie der Limnaeiden enthaltend die Genera *Planorbis*, *Limnaeus*, *Physa* und *Amphipeplea*. Systematisches Conchylien-Cabinet von Martini und Chemnitz, vol 1(17), 2nd edn. Bauer and Raspe, Nürnberg, pp 63–430

Cordellier M, Pfenninger M (2009) Inferring the past to predict the future: climate modelling predictions and phylogeography for the freshwater gastropod *Radix balthica* (Pulmonata, Basommatophora). Mol Ecol 18(3):534–544. https://doi.org/10.1111/j.1365-294X.2008.04042.x

Correa AC, Escobar JC, Durand P et al (2010) Bridging gaps in the molecular phylogeny of the Lymnaeidae (Gastropoda: Pulmonata), vectors of fascioliasis. BMC Evol Biol 10:381. https://doi.org/10.1186/1471-2148-10-381

Correa AC, Escobar JS, Noya O (2011) Morphological and molecular characterization of Neotropic Lymnaeidae (Gastropoda: Lymnaeoidea), vectors of fasciolosis. Infect Genet Evol 11:1978–1988. https://doi.org/10.1016/j.meegid.2011.09.003

Cuvier G (1817) Mémoire sur le Limnée (*helix stagnalis*, Lin.) et le Planorbe (*helix cornea*, ejusd.). In: Cuvier G Mémoires pour servir a l'histoire et a l'anatomie des mollusques. Lebland, Paris, pp 1–14. (separate pagination for each 'memoir')

Da Costa EM (1778) Historia naturalis testaceorum Britanniae, or, the British conchology; containing the descriptions and other particulars of natural history of the shells of Great Britain and Ireland: illustrated with figures. Millan, White, Elmsley and Robson, printed for the author, London. https://doi.org/10.5962/bhl.title.13179

Dall WH (1905) Land and fresh water molluscs of Alaska and adjoining regions. Harriman Alaska Expedition with cooperation of Washington Academy of Sciences 13(i–vii):1–171

Davis GM (1978) Experimental methods in molluscan systematics. In: Fretter V, Peake J (eds) Pulmonates, vol 2A. Academic Press, London, pp 99–169

Davis GM (1994) Molecular genetics and taxonomic discrimination. The Nautilus Supplement 2:3–23

Dayrat B, Conrad M, Balayan S et al (2011) Phylogenetic relationships and evolution of pulmonate gastropods (Mollusca): new insights from increased taxon sampling. Mol Phylogenet Evol 59:425–437. https://doi.org/10.1016/j.ympev.2011.02.014

De Kock KN, Pretorius SJ, Van Eeden JA (1974) Voorlopige kommentar aangaande die voorkomens van die varswaterslakke in den Oranjerivier. 1. In: Van Zinderen Bakker EM (ed) The Orange River. University of The Orange Free State, Bloemfontein, pp 187–212

de Larambergue M (1928) Etude de l'appareil génital de quelques limnées, ses rapports avec la systématique. B Soc Zool Fr 53:491–509

Dillon RT (2000) The ecology of freshwater molluscs. Cambridge University Press, Cambridge etc. https://doi.org/10.1017/CBO9780511542008

Draparnaud JPR (1805) Histoire naturelle des mollusques terrestres et fluviatiles de la France. Plassan; Renaud, Paris et Monpellier. https://doi.org/10.5962/bhl.title.12856

Dreyfuss G, Correa AC, Djuikwo-Teukeng FF (2015a) Differences in compatibility of infection between the liver flukes *Fascioloides magna* and *Fasciola hepatica* in a Colombian population of *Galba* sp. J Helminthol 89:720–726. https://doi.org/10.1017/S0022149X14000509

Dreyfuss G, Vignoles P, Rondelaud D et al (2015b) The mud snail (*Galba truncatula*). Ecology, parasitism and control. Lambert Academic Publishing, Saarbrücken

Dybowski W (1903) Bemerkungen über die gegenwärtige Systematik der Süsswasserschnecken. Nachrichtsblatt der Deutschen Malakozoologischen Gesellschaft 35:130–145

Dybowski B (1913) Bemerkungen und Zusatze zu der Arbeit von Dr. W. Dybowski "Molluscen aus der Uferregion des Baicalsees". Ezhegodnik Zoologicheskogo muzeya Imperatorskoy Akademii nauk 17:165–218

Erhardová-Kotrlá B (1971) The occurrence of *Fascioloides magna* (Bassi, 1875) in Czechoslovakia. Academia, Praha

Eschner A, Vinarski MV, Schnedl SM (2020) Addendum to the examination of the type material of freshwater mollusc species described by J.P.R. Draparnaud. Annalen des Naturhistorischen Museums in Wien, Serie B 122:183–191

Falniowski A (1980) Podrodzaj *Radix* s.str. (Gastropoda, Basommatophora) w Polsce. 1. Pigmentacja i anatomia. Opis *Lymnaea peregra roszkowskiana* subsp. nov. Zeszyty Naukowe Uniwersytetu Jagiellonskiego. Prace Zoologiczne 26:67–108

Fischer P (1880) Manuel de Conchyliologie et de Paléontologie Conchyliologique. Savy, Paris 1:1–112. https://doi.org/10.5962/bhl.title.13213

Fodor I, Hussein AAA, Benjamin PR et al (2020) The unlimited potential of the great pond snail, *Lymnaea stagnalis*. eLife 9:e56962. https://doi.org/10.7554/eLife.56962.sa2

Forbes E, Hanley S (1852–1853) A history of British molluscs and their shells. van Voorst, London. 4:vi+1–616

Freeman G, Lundelius JW (1982) The developmental genetics of dextrality and sinistrality in the gastropod *Lymnaea peregra*. W Roux Arch Dev Biol 191:69–83. https://doi.org/10.1007/BF00848443

Frömming E (1956) Biologie der mitteleuropäischen Süßwasserschnecken. Dunker-Humblot, Berlin

Garbar AV, Korniushin AV (2002) Karyotypes of two European species of the genus *Lymnaea* with disputable taxonomic status (Gastropoda, Pulmonata, Lymnaeidae). Malakologische Abhandlungen / Museum für Tierkunde Dresden 20(2):235–246

Garbar AV, Manilo VV, Korniushin AV (2004) Probable directions of evolution of karyotypes of the European Lymnaeidae (Mollusca, Gastropoda, Pulmonata) in the light of modern concepts of phylogeny of the family. Vestnik zoologii 38(2):29–37. [in Russian]

Ginanni G (1757) Opere postume del conte Giuseppe Ginanni ravennati. Tomo secondo, nel quae si contegnano Testacei marittimi, paludosi e terrestri dell' Adriatico e del territorio di Ravenna, da lui osservati e descritti. G. Zerletti, Venezia

Gittenberger E, Janssen AW, Kuiper JGJ et al (2004) De Nederlandse Zoetwatermolluscen. Recente en fossiele Weekdieren uit Zoet en Brak Water. Nederlandse Fauna. Nationaal Natuurhistorisch Museum Naturalis, KNNV Uitgeverij & EIS-Nederland, Leiden 2:1–288

Glöer P (2002) Die Sußwassergastropoden Nord- und Mitteleuropas: Bestimmungschlussel, Lebenweise, Verbreitung. Die Tierwelt Deutschlands. Conchbooks, Hackenheim 73:1–327

Glöer P (2019) The freshwater gastropods of the west-Palaearctis. Volume 1. Fresh- and brackish waters except spring and subterranean snails. Identification key, anatomy, ecology, distribution. The author, Hetlingen

Gmelin JF (1791) Caroli a Linné Systema Naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Editio decima tertia, aucta, reformata, vol 1(6). G.E. Beer, Leipzig, pp 3021–3910

Gray J (1988) Evolution of the freshwater ecosystem: the fossil record. Palaeogeogr Palaeocl 62:1–214. https://doi.org/10.1016/0031-0182(88)90054-5

Grove DI (1990) A history of human helminthology. C.A.B International, Wallingford

Gurdon JB (2005) Sinistral snails and gentlemen scientists. Cell 123(5):751–753. https://doi.org/10.1016/j.cell.2005.11.015

Hubendick B (1951) Recent Lymnaeidae. Their variation, morphology, taxonomy, nomenclature and distribution. Kungliga Svenska Vetenskapsakademiens Handlingar. Fjärde Serien 3(1): 1–223

Hubendick B (1978) Systematics and comparative morphology of the Basommatophora. In: Fretter V, Peake J (eds) Pulmonates, vol 2A. Academic Press, London, pp 1–47

Inaba A (1969) Cytotaxonomic studies of lymnaeid snails. Malacologia 7(2/3):143–168

Jabbour-Zahab R, Pointier JP, Jourdane J et al (1997) Phylogeography and genetic divergence of some lymnaeid snails, intermediate hosts of human and animal fascioliasis with special reference to lymnaeids from the Bolivian Altiplano. Acta Trop 64:191–203. https://doi.org/10.1016/S0001-706X(96)00631-6

Jackiewicz M (1954) Z badań anatomiczno-porównawczych nad niektórymi gatunkami z rodzaju *Radix* Montfort na terenie Wielkopolski. Prace Komisji Biologicznej, Poznańskie Towarzystwo Przyjaciół Nauk 15(3):1–20

Jackiewicz M (1959) Badania nad zmiennością i stanowiskiem systematycznym *Galba palustris* O.F. Müll. Prace Komisji Biologicznej, Poznańskie Towarzystwo Przyjaciół Nauk 19(3):1–86

Jackiewicz M (1993) Phylogeny and relationships within the European species of the family Lymnaeidae. Folia Malacologica 5:61–95. https://doi.org/10.12657/folmal.005.003

Jackiewicz M (1998) European species of the family Lymnaeidae (Gastropoda, Pulmonata, Basommatophora). Genus 9(1):1–93

Johnson PD, Bogan AE, Brown KM et al (2013) Conservation status of freshwater gastropods of Canada and the United States. Fisheries 38(6):247–282. https://doi.org/10.1080/03632415.2013.785396

Kendall SB (1950) Snail hosts of *Fasciola hepatica* in Britain. J Helminthol 24:63–74. https://doi.org/10.1017/S0022149X00019131

Khokhutkin IM, Vinarski MV, Grebennikov ME (2009) Molluscs of the Urals and the adjacent areas. The family Lymnaeidae (Gastropoda, Pulmonata, Lymnaeiformes). Fasc. 1. Goshchitskiy Publishers, Yekaterinburg. [in Russian]

Kim HY, Choi IW, Kim YR et al (2014) *Fasciola hepatica* in snails collected from water-dropwort fields using PCR. Korean J Parasitol 52:645–652

Klein JT (1753) Tentamen methodi ostracologicæ sive dispositio naturalis cochlidum et concharum in suas classes, genera et species, iconibus singulorum generum aeri incisis illustrata etc. Wishoff, Leiden. https://doi.org/10.5962/bhl.title.117134

Klotz J (1889) Beitrag zur Entwicklungsgeschichte und Anatomie des Geschlechtsapparates von *Lymnaeus*. Jenaische Zeitschrift für Naturwissenschaft 23:1–40

Korobkov IA (1955) A handbook and methodical guide to tertiary molluscs. Gastropoda. Gostoptekhizdat, Leningrad. [in Russian]

Krauss F (1848) Die Südafrikanischen Molluscen. Ein Beitrag zur Kenntniss der Molluscen des Kap- und Natallandes und zur Geographischen Verbreitung derselben mit Beschreibung und Abbildung der neuen Arten. Ebner and Seubert, Stuttgart. https://doi.org/10.5962/bhl.title.13936

Kruglov ND (1986) On the specificity of pond snails (Pulmonata, Lymnaeidae) to infestation by the trematode parthenitae and its analysis for the purposes of systematics and parasitology. Zool Zh 65(12):1799–1807. [in Russian]

Kruglov ND (2005) Lymnaeid snails of Europe and Northern Asia. Smolensk State Pedagogical University Press, Smolensk. [in Russian]

Kruglov ND, Starobogatov YI (1985) Methods of experimental hybridization and some results of its applications in the taxonomy of Lymnaeidae. Malacol Rev 18:21–35

Kruglov ND, Starobogatov YI (1993a) Annotated and illustrated catalogue of species of the family Lymnaeidae (Gastropoda Pulmonata Lymnaeiformes) of Palaearctic and adjacent river drainage areas Part I. Ruthenica Russian Malacol J 3(1):65–92

Kruglov ND, Starobogatov YI (1993b) Annotated and illustrated catalogue of species of the family Lymnaeidae (Gastropoda Pulmonata Lymnaeiformes) of Palaearctic and adjacent river drainage areas Part II. Ruthenica Russian Malacol J 3(1):161–180

Küster HC (1862) Die Gattungen *Limnaeus*, *Amphipeplea*, *Chilina*, *Isidora* und *Physiopsis*. Martini und Chemnitz Systematisches Conchylien-cabinet. Bauer und Raspe, Nürnberg 1(17):1–77

Lamarck JBPA d M (1822) Histoire naturelle des animaux sans vertèbres. chez l'Auteur, Paris 6(2): 1–232. https://doi.org/10.5962/bhl.title.12712

Leuckart R (1882) Zur Entwickelungsgeschichte des Leberegels Zweite Mittheilung. Zool Anz 5: 524–528

Linnaeus C (1758) Systema naturæ per regna tria naturæ, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Editio decima, reformata. Laurentius Salvius, Stockholm. https://doi.org/10.5962/bhl.title.542

Lister M (1678) Historiae animalium Angliae tres tractatus. Unus de Araneis. Alter de Cochleis tum terrestribus tum fluviatilibus. Tertius de Cochleis marinis. Quibus adjectus est quartus de Lapidibus ejusdem insulae ad cochlearum quandam imaginem figuratis J. Martyn, London. https://doi.org/10.5962/bhl.title.39518

Lister M (1695) Exercitatio anatomica altera, in qua maximè agitur de buccinis fluviatilibus and marinis etc. In: Smith S, Walford B (eds) London. https://doi.org/10.5962/bhl.title.39640

Locard A (1893) Coquilles des eaux douces et saumâtres de France. Description des familles, genres et espèces. Alexandre Rey, Lyon. https://doi.org/10.5962/bhl.title.12982

Lounnas M, Correa AC, Vázquez AA et al (2017) Self-fertilization, long-distance flash invasion and biogeography shape the population structure of *Pseudosuccinea columella* at the worldwide scale. Mol Ecol 26:887–903. https://doi.org/10.1111/mec.13984

Lounnas M, Correa AC, Alda P et al (2018) Population structure and genetic diversity in the invasive freshwater snail *Galba schirazensis*. Can J Zool 96(5):425–435. https://doi.org/10.1139/cjz-2016-0319

Mage C, Reynal P, Rondelaud D et al (1989) Mise en pratique du contrôle de l'infestation par *Fasciola hepatica* chez des bovins limousins. Bulletin des Groupements Techniques Vétérinaires 347:5–10

Mahulu A, Clewing C, Stelbrink B et al (2019) Cryptic intermediate snail host of the liver fluke *Fasciola hepatica* in Africa. Parasite Vectors 12:573. https://doi.org/10.1186/s13071-019-3825-9

Malek EA (1980) Snail-transmitted parasitic diseases, in two volumes. CRC Press, Boca Raton, FL

Mas-Coma S, Bargues MD (1997) Human liver flukes: a review. Res Rev Parasitol 57:145–218

McMahon RF (1983) Physiological ecology of freshwater pulmonates. In: Russell-Hunter WD (ed) The Mollusca, vol 6. Academic Press, Orlando etc, pp 360–430

Mehl S (1932) Die Lebensbedingungen der Leberegelschnecke (*Galba truncatula* Müller). Untersuchungen über Schale, Verbreitung, Lebensgeschichte, natürliche Feinde und Bekämpfungsmöglichkeiten. Arbeiten aus der Bayerischen Landesanstalt für Pflanzenbau und Pflanzenschutz 2:1–177

Meier-Brook C (1993) Artaufassungen in Bereich der limnischen Molluscen und ihr Wandel im 20 Jahrhundert. Arch Molluskenkd 122:133–147

Meshcheryakov VN (1990) The common pond snail, *Lymnaea stagnalis*. In: Dettlaff TA, Wassetsky SG (eds) Animal species for developmental studies: invertebrates. Plenum Publishing Corp, New York, pp 69–132. https://doi.org/10.1007/978-1-4613-0503-3_5

Mezhzherin SV, Garbar AV, Korshunova ED et al (2008) The analysis of morphological and genetic variation of the snail, *Lymnaea stagnalis* s. 1. (Gastropoda, Lymnaeidae), in Ukraine. Vestnik Zoologii 42:339–345. [in Russian]

Michelin H (1831) *Lymnaeus rubiginosus*. Magasin de Zoologie, journal destiné à Établir une correspondance entre les Zoologists de tous les pays, et à leur faciliter les moyens de publier les espèces nouvelles ou peu connues qu'ils possedent. 2^{me} sect. Mollusques et Zoophytes 1: No. 22

Middendorff AT (1851) Mollusken. In: Middendorff AT (ed) Reise in den äussersten Norden und Osten Sibiriens. Band II. Zoologie. Theil 1. Wirbellose Thiere. Kaiserlische Akademie der Wissenschaften, Saint-Pétersburg, pp 163–465. https://doi.org/10.5962/bhl.title.52029

Mozley A (1957) Liver fluke snails in Britain. H. K. Lewis and Co., London

Müller OF (1774) Vermium terrestrium et fluviatilium seu animalium infusorium, helminthicorum et testaceorum non marinorum succincta historia. Heineck et Faber, Havniae et Lipsiae 2:1–214. https://doi.org/10.5962/bhl.title.46299

Oheimb PV v, Albrecht C, Riedel F et al (2011) Freshwater biogeography and limnological evolution of the Tibetan Plateau – insights from a plateau-wide distributed gastropod taxon (*Radix* spp.). PLoS One 6:e26307. https://doi.org/10.1371/journal.pone.0026307

Økland J (1990) Lakes and snails. Environment and Gastropoda in 1,500 Norwegian lakes, ponds and rivers. Universal Book Services / Dr. W. Backhuys Publ, Oegstgeest

Over HJ (1962) A method of determining the liver fluke environment by means of the vegetation type. Bulletin de l'Office International des Epizooties 58:297–304

Over HJ (1967) Ecological biogeography of *Lymnaea truncatula* in The Netherlands. PhD Thesis, University of Utrecht, The Netherlands

Patterson CM, Burch JB (1978) Chromosomes of pulmonate molluscs. In: Fretter V, Peake J (eds) Pulmonates, vol 2A. Academic Press, London, pp 171–217

Patzer HE (1927) Beiträge zur Biologie der Leberegelschnecke, *Galba* (*Limnaea*) *truncatula* Müll. Zool Jahrb Allg Zool 53:321–372

Pchelintsev VF, Korobkov IA (eds) (1960) Fundamentals of Paleontology: a manual for Paleontologists and geologists of the U.S.S.R. Molluscs – Gastropoda. Academy of Sciences of the USSR Press, Moscow-Leningrad. [in Russian]

Pecheur M (1974) Lutte stratégique contre la distomatose. Comptes-Rendus de Recherches, Travaux du Centre de Recherches sur les Maladies Parasitaires des Animaux Domestiques. IRSIA, Bruxelles 38:85–150

Pereira AE, Uribe N, Pointier JP (2020) Lymnaeidae from Santander and bordering departments of Colombia: morphological characterization, molecular identification and natural infection with *Fasciola hepatica*. Vet Parasitol Reg Stud Rep 20:100408. https://doi.org/10.1016/j.vprsr.2020.100408

Perrot JL, Perrot M (1938) Note sur les chromosomes de cinq espèces de limnées. Compte-rendu des séances de la Société de physique et d'histoire naturelle de Genève 53:92–93

Peters BG (1938a) Biometrical observations on shells of *Limnaea* species. J Helminthol 16(4): 181–212. https://doi.org/10.1017/S0022149X00018587

Peters BG (1938b) Habitats of *Limnaea truncatula* in England and Wales during dry seasons. J Helminthol 16(4):213–260. https://doi.org/10.1017/S0022149X00018599

Pfenninger M, Cordellier M, Streit B (2006) Comparing the efficacy of morphological and DNA-based taxonomy in the freshwater gastropod genus *Radix* (Basommatophora, Pulmonata). BMC Evol Biol 6:100. https://doi.org/10.1186/1471-2148-6-100

Piechocki A, Wawrzyniak-Wydrowska B (2016) Guide to freshwater and marine Mollusca of Poland. Bogucki Wydawnictwo Naukowe, Poznań

Pointier JP (ed) (2015) Freshwater molluscs of Venezuela and their medical and veterinary importance. Conchbooks, Harxheim

Pointier JP, Vàzquez AA (2020) Lymnaeoidea, Lymnaeidae. In: Damborenea C, Rogers DC, Thorp JH (eds) Thorp and Covich's freshwater invertebrates, Volume 5: Keys to Neotropical and Antarctic Fauna. Academic Press, London, pp 281–290

Ponder WF, Waterhouse J (1997) A new genus and species of Lymnaeidae from the lower Franklin River, South-Western Tasmania. J Molluscan Stud 63:441–468. https://doi.org/10.1093/mollus/63.3.441

Puslednik L, Ponder WF, Dowton M et al (2009) Examining the phylogeny of the Australasian Lymnaeidae (Heterobranchia: Pulmonata: Gastropoda) using mitochondrial, nuclear and morphological markers. Mol Phylogenet Evol 52(3):643–659. https://doi.org/10.1016/j.ympev.2009.03.033

Remigio EA (2002) Molecular phylogenetic relationships in the aquatic snail genus *Lymnaea*, the intermediate host of the causative agent of fascioliasis: insight from broader taxon sampling. Parasitol Res 88:687–696. https://doi.org/10.1007/s00436-002-0658-8

Remigio EA, Blair D (1997a) Molecular systematics of the freshwater snail family Lymnaeidae (Pulmonata: Basommatophora) utilising mitochondrial ribosomal DNA sequences. J Molluscan Stud 63(2):173–185. https://doi.org/10.1093/mollus/63.2.173

Remigio EA, Blair D (1997b) Relationships among problematic North American stagnicoline snails (Pulmonata: Lymnaeidae) reinvestigated using nuclear ribosomal DNA internal transcribed spacer sequences. Can J Zool 75:1540–1545. https://doi.org/10.1139/z97-779

Roberts EW (1950) Studies on the life-cycle of *Fasciola hepatica* (Linnaeus) and of its snail host, *Limnaea* (*Galba*) *truncatula* Müller in the field and under controlled conditions. Ann Trop Med Parasit 44:187–206. https://doi.org/10.1080/00034983.1950.11685441

Rondelaud D, Barthe D (1982) Les générations rédiennes de *Fasciola hepatica* L. chez *Lymnaea truncatula* Müller. Pluralité des schémas de développement. Ann Parasit Hum Comp 57:639–642

Rondelaud D, Vignoles P, Dreyfuss G et al (2006) The control of *Galba truncatula* (Gastropoda: Lymnaeidae) by the terrestrial snail *Zonitoides nitidus* on acid soils. Biol Control 39:290–299

Rondelaud D, Belfaiza M, Vignoles P et al (2009) Redial generations of *Fasciola hepatica*: a review. J Helminthol 83:245–254. https://doi.org/10.1017/s0022149x09222528

Roszkowski W (1914a) Contribution à l'étude des Limnées du lac Léman. Rev Suisse Zool 22(15): 457–539

Roszkowski W (1914b) Note sur l'appareil génital de *Limnaea auricularia* L. et de *Limnaea ovata* Drap. Zool Anz 44(4):175–179

Roszkowski W (1925) Contributions to the knowledge of the family Lymnaeidae. II. Some new data to the knowledge of the Altai *Lymnaea*. Annales Zoologici Musei Polonici Historiae Naturalis 4(4):277–281

Roszkowski W (1928) The distribution of Lymnaeids in Europe and in North America, with relation to Wegener's theory. Annales Zoologici Musei Polonici Historiae Naturalis 7(2–3):64–97

Roszkowski W (1929) Contributions to the study of the family Lymnaeidae. I. On the systematic position and the geographical distribution of the genus *Myxas* J. Sowerby. Annales Zoologici Musei Polonici Historiae Naturalis 8(2):64–97

Russell-Hunter WD (1964) Physiological aspects of ecology in non-marine mollusks. In: Wilbur KM, Yonge CM (eds) Physiology of Mollusca. Academic Press, London, pp 83–125

Russell-Hunter WD (1978) Ecology of freshwater pulmonates. In: Fretter V, Peake J (eds) Pulmonates, vol 2A. Academic Press, London, pp 335–384

Saadi AJ, Davison A, Wade CM (2020) Molecular phylogeny of freshwater snails and limpets (Panpulmonata: Hygrophila). Zool J Linnean Soc 190(2):518–531. https://doi.org/10.1093/zoolinnean/zlz177

Saito T, Hirano T, Ye B et al (2021) A comprehensive phylogeography of the widespread pond snail genus *Radix* revealed restricted colonization due to niche conservatism. Ecol Evol 11(24): 18446–18459. https://doi.org/10.1002/ece3.8434

Say T (1817) Conchology. In: Nicholson W (ed) American edition of the British Encyclopedia, or, dictionary of arts and sciences comprising an accurate and popular view of the present improved state of human knowledge, 1st edn, 2:A3–C6 [= 1–20], pp [1–4]

Say T (1821) Description of univalve shells of the United States. J Acad Natl Sci Phila 2(1): 149–179

Schniebs K, Glöer P, Vinarski M et al (2011) Intraspecific morphological and genetic variability in *Radix balthica* (Linnaeus 1758) (Gastropoda: Basommatophora: Lymnaeidae) with morphological comparison to other European *Radix* species. J Conchol 40(6):657–678

Schniebs K, Glöer P, Vinarski M et al (2013) Intraspecific morphological and genetic variability in the European freshwater snail *Radix labiata* (Rossmaessler, 1835) (Gastropoda: Basommatophora: Lymnaeidae). Contrib Zool 82(1):55–68. https://doi.org/10.1163/18759866-08201004

Schrank von Paula F (1803) Fauna Boica. Durchgedachte Geschichte der in Baiern einheimischen und zahmen Thiere. Philipp Krull: Landshut 3(2):1–372. https://doi.org/10.5962/bhl.title.44923

Schröter JS (1779) Die Geschichte der Flußconchylien mit vorzüglicherRücksicht auf diejenigenwelche in den thüringischen Wassern leben.Gebauer, Halle

Seba A (1758) Locupletissimi rerum naturalium thesauri accuratadescriptio, et iconibus artificiosissimis expressio, per universamphysices historium. Tomus III. J. Wetsten, W. Smith & Jansson-Waesbergios, Amsterdam

Sindou P, Cabaret J, Rondelaud D (1991) Survival of snails and characteristics lesions of *Fasciola hepatica* infection in four European species of *Lymnaea*. Vet Parasitol 40:47–58

Sitnikova TY, Kijashko PV, Sysoev AV (2012) Species names of J.-R. Bourguignat and their application in current taxonomy of freshwater gastropods of the Russian fauna. The Bulletin of the Russian Far East Malacological Society 15(16):87–116

Sitnikova TY, Sysoev AV, Prozorova LA (2014) Types of freshwater gastropods described by Ya.I. Starobogatov, with additional data on the species: family Lymnaeidae. Zoologicheskie Issledovania 16:7–37

Smith G (1981) A three-year study of *Lymnaea truncatula* habitats, disease foci of fascioliasis. Brit Vet J 17:329–342. https://doi.org/10.1016/S0007-1935(17)31638-X

Sowerby GB II (1872) Monograph of the genus *Limnaea*. Conchologia iconica, or, illustrations of the shells of molluscous animals, vol 18. Reeve and Co, London, pp 1–15. unpaginated text

Stadnichenko AP (2004) Pond snails and limpet snails (Lymnaeidae and Acroloxidae) of Ukraine. Tsentr uchebnoi literatury, Kiev. [in Russian]

Stadnichenko AP (2006) Lymnaeidae and Acroloxidae of Ukraine: sampling and studying methods, biology, ecology, their practical importance. Ruta Press, Zhytomyr. [in Russian]

Starobogatov YI (1967) On the systematization of freshwater pulmonate molluscs. Trudy Zoologicheskogo Instituta AN SSSR 42:280–304. [in Russian]

Starobogatov YI (1970) Molluscan fauna and zoogeographic zonation of continental freshwater bodies of the world. Nauka, Leningrad. [in Russian]

Stefanski W (1959) Occurrence and ecology of *Galba truncatula* in Poland. Wiad Parazytol 5:311–314. [in Polish]

Strong EE, Gargominy O, Ponder WP et al (2008) Global diversity of gastropods (Gastropoda; Mollusca) in freshwater. Hydrobiologia 595:149–166. https://doi.org/10.1007/s10750-007-9012-6

Sturtevant AH (1923) Inheritance of direction of coiling in *Limnaea*. Science 58:269–270. https://doi.org/10.1126/science.58.1501.269

Subba Rao MV (1989) Handbook: freshwater molluscs of India. Zoological Survey of India, Calcutta

Swammerdam J (1738) Bybel der natuure of historie der insecten, tot zeekere zoorten gebracht: door voorbeelden, ontleedkundige onderzoekingen van veelerhande kleine gediertens, als ook door kunstige kopere plaaten opgeheldert. Verrykt met ontelbaare waarnemingen van nooit ontdekte zeldzaamheden in de natuur. Alles in de hollandse, des auteurs moedertaale, beschreven. Hier by komt een voorreeden, waar in het leven van den auteur beschreven is door Herman Boerhaave. De Latynsche overzetting heeft bezorgt Hieronimus David Gaubius. II. deelen. I. Severinus, B. van der Aa and P. van der Aa, Leiden, 2:551–990. https://doi.org/10.5962/bhl.title.119987

Taktakishvili IG (1967) The historical development of the family Valenciennidae. Metsniereba, Tbilisi. [in Russian]

Taylor DW (1988) Aspects of freshwater mollusc ecological biogeography. Palaeogeogr Palaeoclim 62:511–576. https://doi.org/10.1016/0031-0182(88)90071-5

Taylor DW, Sohl NF (1962) An outline of gastropod classification. Malacologia 1(1):7–32

Thiele J (1931) Handbuch der Systematischen Weichtierkunde, vol 2. Gustav Fischer Verlag, Jena, pp 377–778

Thomas AP (1882) Second report of experiments on the development of the liver fluke (*Fasciola hepatica*). J Roy Agr Soc Engl 18:439–455

Thompson FG (2011) An annotated checklist and bibliography of the land and freshwater snails of Mexico and Central America. Bull Fla Mus Nat Hist 50(1):1–299

Throckmorton LH (1968) Biochemistry and taxonomy. Ann Rev Entomol 13:99–114. https://doi.org/10.1146/annurev.en.13.010168.000531

Troschel FH (1839) Ueber die Gattung *Amphipeplea* Nilss. Archiv für Naturgeschichte 5(1): 177–184

van Beneden PJ (1838) Mémoire sur le *Limneus glutinosus*. Nouveaux mémoires de l'Académie Royale des Sciences et Belles-Lettres de Bruxelles 11(22):3–16

Vázquez AA, Pilar A, Lounnas M et al (2018) Lymnaeid snails hosts of *Fasciola hepatica* and *Fasciola gigantica* (Trematoda: Digenea): a worldwide review. CAB Rev Perspect Agric Vet Sci Nutr Nat Resour 13:1–15. https://doi.org/10.1079/PAVSNNR201813062

Vázquez AA, Vargas M d, Alba A et al (2019) Reviewing *Fasciola hepatica* transmission in the West Indies and novel perceptions from experimental infections of sympatric vs. allopatric snail/fluke combinations. Vet Parasitol 275:108955. https://doi.org/10.1016/j.vetpar.2019.108955

Vinarski MV (2013) One, two, or several? How many lymnaeid genera are there? Ruthenica Russian Malacol J 23(1):41–58

Vinarski MV (2014) The birth of malacology: when and how? Zoosyst Evol 90(1):1–5. https://doi.org/10.3897/zse.90.7008

Vinarski MV (2015) Conceptual shifts in animal systematics as reflected in the taxonomic history of a common aquatic snail species (*Lymnaea stagnalis*). Zoosyst Evol 91:91–103. https://doi.org/10.3897/zse.91.4509

Vinarski MV (2016) Annotated type catalogue of lymnaeid snails (Mollusca, Gastropoda) in the collection of the Natural History Museum, Berlin. Zoosyst Evol 92(1):131–152. https://doi.org/10.3897/zse.92.8107

Vinarski MV (2019) 11. Class Gastropoda. In: Rogers DC, Thorp JH (eds) Thorp and Covich's freshwater invertebrates. Vol. IV. Keys to Palaearctic Fauna. Academic Press, London, pp 310–345

Vinarski MV, Kantor YI (2016) Analytical catalogue of fresh and brackish water molluscs of Russia and adjacent countries. A.N. Severtsov Institute of Ecology and Evolution of RAS, Moscow

Vinarski M, Schniebs K, Glöer P et al (2011) The taxonomic status and phylogenetic relationships of the genus *Aenigmomphiscola* Kruglov et Starobogatov, 1981 (Gastropoda: Pulmonata: Lymnaeidae). J Nat Hist 45(33–34):2049–2068. https://doi.org/10.1080/00222933.2011.574800

Vinarski MV, Schniebs K, Glöer P et al (2012) The steppe relics: taxonomic study on two lymnaeid species endemic to the former USSR (Gastropoda: Pulmonata: Lymnaeidae). Arch Molluskenkd 141(1):67–85. https://doi.org/10.1127/arch.moll/1869-0963/141/067-085

Vinarski MV, Nekhaev IO, Glöer P et al (2013) Type materials of freshwater gastropod species described by C.A. Westerlund and accepted in current malacological taxonomy: a taxonomic and nomenclatorial study. Ruthenica Russian Malacol J 23(2):79–108

Vinarski MV, Aksenova OV, Bespalaya YV et al (2016) *Radix dolgini*: the integrative taxonomic approach supports the species status of a Siberian endemic snail (Mollusca, Gastropoda, Lymnaeidae). C R Biol 339(1):24–36. https://doi.org/10.1016/j.crvi.2015.11.002

Vinarski MV, Clewing C, Albrecht C (2019) Family Lymnaeidae. In: Lydeard C, Cummings KS (eds) Freshwater molluscs of the world: a distribution atlas. Johns Hopkins University Press, Baltimore, MD, pp 158–162

Vinarski MV, Aksenova OV, Bolotov IN (2020) Taxonomic assessment of genetically-delineated species of radicine snails (Mollusca, Gastropoda, Lymnaeidae). Zoosyst Evol 96(2):577–608. https://doi.org/10.3897/zse.96.52860

Wagner J (1927) Nouvelles contributions a l'anatomie de l'appareil génital des limnees de Hongrie. Állattani Közlemények 24(1–2):29–39. [in Hungarian]

Wagner H (1929) Zur Variation von *Limnaea* und biometrische Untersuchungen an *Planorbis*. Zool Anz 80(7/9):183–193

Walter HJ (1969) Illustrated biomorphology of the "*angulata*" lake form of the basommatophoran snail *Lymnaea catascopium* Say. Malacol Rev 2:1–102

Welter-Schultes F (2012) European non-marine molluscs: a guide for species identification. Planet Poster Editions, Göttingen

Wenz W (1923) Gastropoda extramarina tertiaria, vol 4. W. Junk, Berlin, pp 1069–1420

Wenz W, Zilch A (1959–1960) Gastropoda. Teil 2. Euthyneura. In: Schindewolf OH (ed) Handbuch der Paläozoologie. Gebrüder Borntraeger, Berlin. 6(2):ii+1–834

Westerlund CA (1885) Fauna der in der Paläarktischen Region (Europa, Kaukasien, Sibirien, Turan, Persien, Kurdistan, Armenien, Mesopotamien, Kleinasien, Syrien, Arabien, Egypten, Tripolis, Tunisien, Algerien und Marocco) lebenden Binnenconchylien. V. Fam. Succineidae, Auriculidae, Limnaeidae, Cyclostomidae und Hydrocenidae. H. Ohlsson, Lund

Wright CA (1971) Flukes and snails. George Allen and Unwin, London

Yen TC (1939) Die Chinesische Land- und Süsswasser-Gastropoden in Natur-Museums Senckenberg. Abhandlungen der Senckenbergischen naturforschenden Gesellschaft 444:1–233

Zhadin VI (1923) The variation of *Limnaea stagnalis* in waterbodies of the vicinities of Murom. Russkiy Gidrobiologicheskiy Zhurnal 2(97–106):173–178. [in Russian]

Zhadin VI, Pankratova VA (1931) Studies on biology of mollusks – vectors of fasciolosis, and the development of measures against them. Raboty Okskoi Biologicheskoi Stantsii 6:79–157. [in Russian]