The Anatomy of *Arion flagellus* Collinge, 1893, Present on the Iberian Peninsula (Gastropoda: Arionidae: Terrestria Nuda)  
by  
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Abstract. The presence of *Arion flagellus* in Galicia (NW Spain) is reported. The internal and external morphology (including spermatophore) and copulation of Galician specimens are described, and are discussed with reference to English specimens and to the Portuguese Arionidae described in the last century by Morelet, Mabille, Pollonera, and Simroth.

INTRODUCTION  
Specific identification of the large Arionidae (the large Arionidae are taken to be those that measure at least 80 mm in vivo) of the Iberian Peninsula is difficult if the considered individuals are few in number or incompletely developed. Juveniles may have bands on their mantles and backs that may no longer be present in adults, and body coloring is generally lighter in juveniles than in adults. Many juveniles have a whitish or light gray sole, which in adults, depending on the species, becomes orange, yellowish, black, or light in the center and dark laterally. The genitalia of juveniles are easily distinguished from those of subadults or adults, but those of subadults, adults, and seniles are harder to tell apart, all three sets being completely developed and differing only in the relative proportions of their parts. Identification based on the genital morphology of a small number of specimens is further complicated by the fact that in specimens that have recently copulated (as demonstrated by the presence of the whole spermaphore in the genitalia) the epiphallus is larger in diameter and shorter than in specimens that have a fragmented spermatophore or have not mated.

One structure that can, in principle, give information about the identity of species is the spermatophore. Davies (1987) noted that a distinctive form of spermatophore must indicate the reproductive isolation of a good species, and she went on to assert that if each variable species of *Arion* is characterized by the possession of a distinctive, and much less variable, spermatophore, then the organs concerned in the production and exchange of spermatophores must be of considerable taxonomic importance. Clearly the length of the spermatophore must be of some importance, since long ones will take longer to be exchanged than short ones. The sculpture of the spermatophore, which is produced by the lumen of the epiphallus, may also be significant for transfer. The ligula and copulatory behavior ought to be important too, although Davies (1987) pointed out that in stabilizing the pair, and perhaps in stimulating the mating process, the position and movements of the ligula may be more important than its changeable shape and size; upon evagination, in some species the ligula is firmly pressed against that of the mate, in others it is rested on the mate's flanks, and in still others it is used to embrace the mate's tail.

Thus, the identification of species within the Arionidae is not easy, since the sizes and proportions of their organs can vary with both intrinsic factors (developmental stage, cycle phase, etc.) and extrinsic factors (degree of relaxation upon death, preservation, manipulation, etc.). Simroth (1889), recognizing the problem, wrote that the dividing lines between the species of the genus *Arion* are less clear than those between the Limacidae, which is why new species are so easily created. He also felt that what would best enable us to judge what ought to be included under the same name is knowledge of the fauna as a whole, starting from postembryonic development and biology; for Simroth, this investigation would have to take place on the west coast of Europe, the center of the creation of the Arionidae.

The situation outlined above, together with methodological advances in the study and description of new taxa,
make it desirable to re-examine the types, and preferably also the toptypes, of all the species described in the last century on the basis of few and often incompletely developed specimens. This re-examination should be supported by the study of whole populations in various biotopes and in all seasons in order to determine the spatial and temporal variability of the species. Only in this way can the lines dividing species be firmly established.

_Arion flagellus_ was described by Collinge (1893) from Ireland. The large Portuguese _Arion_ species were studied in the last century by Morelet (1845), Mabille (1868), Pollonera (1887, 1889, 1890), and Simroth (1886, 1891). Morelet described, solely on the basis of external morphology, a series of new species (_A. sulcatus, A. timidus, and A. fuliginosus_) and re-described several existing species.

Mabille included Morelet's new species in his genus _Baudonia_, and created _A. lustianicus_ with part of _A. rufus sensu_ Morelet, and _A. pascalianus_ with _A. fusca sensu_ Morelet. All of Morelet's and Mabille's species were accepted by Pollonera, who also described two new species (_A. dasilvae_ and _A. nobrei_). Simroth (1886) created _A. hispanicus_, but later recognized only _A. ater_ and _A. lustianicus_ as good species, treating _A. hispanicus_ as a synonym for the latter. Nobre (1941) considered all large Portuguese _Arion_ to be _A. ater_. Seixas (1976), however, reported finding _A. ater, A. lustianicus_ and _A. subfuscus_, and Castillejo & Roal (1977) recently recognized _A. ater, A. nobrei, A. lustianicus, A. fuliginosus_, and _A. intermedius_ in a revision of the genus _Arion_ in Portugal on the basis of the anatomy of toptypes collected by systematic sampling.
Specimens of *Arion flagellus* (deposited in the collection of the Departamento de Biología Animal, Facultad de Biología, Universidad de Santiago, Spain) were collected in Galicia between 1979 and 1984 by standard methods for capture, transport, killing, fixation, and preservation. To record external morphology, the most representative specimens were photographed at the time of capture. External morphology and genitalia were drawn to scale using a camera lucida and a binocular magnifier. Copulation was drawn from slides taken *in situ* with no scale.

The following specimens sent by Dr. S. M. Davies were used for comparison: *Arion flagellus* from Bramley Bank, Croydon, England; *A. lusianicus* collected in the garden of 63 Beechwood Road, South Croydon, Surrey, England; and *A. subfuscus* from Coulson Woods, Surrey, England. We also studied specimens of *A. subfuscus* collected to the north of Antwerp, Belgium, and sent by Dr. T. Backeljau.

In what follows, the morphology of the specimens we found in the northwest of Spain is described and compared with the English toptypes.
Explanation of Figures 7 to 9

Figures 7–9, Arion flagellus, Sierra del Gistral (Lugo). Various views of genitalia. Key: A, atrium; Ag, albumen gland; Ep, epiphallus; Fo, free oviduct; Hd, hermaphroditic duct; Ot, ovotestis; R, retractor muscle; Sp, spermatheca; Spo, spermoviduct; Vd, vas deferens. Scale 1 mm.

Arion flagellus: Collinge, 1893

Explanation of Figures 10 and 11

Figures 10 and 11. *Ariol flagellus*, Sierra del Gistral (Lugo). Figure 10. Ligula. Figure 11. Spermatophore with detail of toothlets. Key: Fd, fold; Li, ligula. Scale 1 mm.

(Sierra del Gistral, Lugo), U.T.M. = 29TJP21, 18 October 1984 (13 specimens).

The species may be very abundant in Galicia, since most reports of *Ariol lusitanicus* may in fact refer to *Ariol flagellus*. Specimens were found on acid soil over granite under vegetation dominated by pines, eucalyptus and, to a lesser extent, chestnut and birch.

Description: This is a large slug and the fully extended length in vivo can exceed 90 mm. In 70% alcohol, specimens shrink and measure 50 to 70 mm (Figures 1–3). The live body color is dark gray, with a greenish yellow or greenish chestnut flush (the green coloration of the Galician *Ariol flagellus* is striking enough for country folk in some places to refer to this species as the "green slug that lives in the meadows"); its flanks are lighter, greenish yellow predominating over the gray. The back and mantle of some specimens have two darker bands, the one on the right surrounding the pneumostome; like the flanks, the dorsal area between the bands is lighter. Juveniles are lighter colored than adults, with or without bands. In alcohol, juveniles and adults turn darker and the dorsal bands tend to disappear. The dermal tubercles are prominent, as in the Portuguese *Ariol lusitanicus*, forming longitudinal keels when the animal contracts. The foot fringe is greenish yellow or greenish orange and the lineoles (vertical lines) are black.
The tentacles and the back of the head are black. Both adults and juveniles show a uniformly pale greenish yellow or greenish orange sole. The body mucus is whitish or colorless, turning a dirty white upon contact with alcohol; the sole mucus is orange. The limacella (internal shell) is formed of more or less aggregated calcareous grains.

*Organs in situ* (Figure 4). The digestive tract (Figure 5) and pallial complex (Figure 6) have the characteristic toponography of the genus. The arteries feeding the digestive gland and tract are white in specimens from Ferreira de Valadouro and Cuadramón preserved in 70% alcohol.

*Genitalia* (Figures 7, 8, 9, 12). The ovotestis is voluminous and is made up of brown acini. The hermaphroditic duct is long and straight, and the albumin gland almond-shaped, somewhat curved in the middle. The spermoviduct is long and has no distinguishing color. The epiphallus measures 20–30 mm in adults containing a whole spermatophore, while in subadults and seniles it is only 14–25 mm in length; on the other hand, the vas deferens in these latter classes measures 10–18 mm, while in adults containing a whole spermatophore its length is 10–15 mm. The juvenile epiphallus is up to three times longer than the vas deferens, both structures together measuring 13 mm or less. The junction between the vas deferens and the epiphallus is marked by a constriction, and the epiphallus has a strong, annular thickening at its entry into the proximal atrium. The distal free oviduct is as long as the vas deferens (half as long as the epiphallus), with a pronounced lateral dilation housing the ligula (stimulator organ); the proximal part of the distal free oviduct can have a lateral elbow. The proximal free oviduct is one-half the length of the distal free oviduct. The ligula (Figures 10, 13) possesses a circular or oblong shape, and is generally located in the proximal third of the distal free oviduct; in some specimens (Figure 13) there are one or two folds that continue to the proximal atrium, where they may give rise to a small dilation at the proximal end of the spermatheca duct. The orifice of the proximal free oviduct may open inside or outside the ligula. The spermatheca (bursa copulatrix) is spherical or pear-shaped, its duct being shorter than the epiphallus, with, in some specimens, a papilla located at the commencement of the duct and pointing towards the proximal atrium (Figure 10). The proximal atrium is small; and the distal atrium is
more or less spherical, covered externally by tissue of glandular appearance. The oviduct retractor muscle appears strongly united with the retractor of the bursa copulatrix, from which fascicles sometimes extend to the annular thickening of the epiphalus; in the inferior distal free oviduct, parietal muscles are sometimes united. No part of the genitalia has black pigmentation except the distal epiphallus near the annular ring (this pigmentation is not a result of preservation in alcohol, being found in live specimens).

Spermatophore (Figure 11). The spermatophore is cylindrical, and measures 20 mm long, tapering to a rounded knob at one end and to a point at the other. Upon extraction it resumes the U-shape it has inside the genitalia after transfer. A longitudinal serrate crest with tall, narrow, closely packed teeth runs almost the whole length, dwindling at its ends to merge with the body of the spermatophore.

Copula (Figures 14–24). Copulating Arion flagellus were photographed on the night of 17 September 1984 at Ferreira de Valadouro (Lugo); relative humidity was close to 100%. The entire event was not witnessed, but certainly lasted at least 45 min.

In the precopulation phase, the two individuals move
Explanation of Figures 17 to 20

Explanation of Figures 21 to 24

one behind the other, the rear one licking the other's caudal area. They then curl into interlocking Cs with their genital orifices opposite each other, and shortly afterwards the posterior part of genitals (stirium and free oviduct) are evaginated or evored (Figure 14) together with the distal parts of the free oviduct and the ligulas, which grip the mate's tail (Figures 14, 15, 19). Copulation is static (in particular they do not move in circles), except that they often lift their heads, with the tentacles retracted, and lick or scrape the mate with the protruded mandible and radula (Figures 15, 16, 18). At the end of copulation (Figure 24), they begin to extend their tentacles and move away in opposite directions. At this point the amber-colored tips of the spermatophores are visible (Figure 24) and the ligulas are still evaginated. The two individuals separate and invaginate their genitalia very rapidly; once separated they curl up and lick the spot where the other had placed its ligula.

DISCUSSION

The dissected Galician specimens of Arion flagellus resemble the English specimens closely, the proportions of the various parts of the genitalia and the size and appearance of the spermatophore being identical. The main difference concerns copulation. Davies (1987) states that most of the evaginated anterior part of the genitalia of copulating English specimens lies underneath the animals, and cannot be seen until they start to separate; the evaginated anterior part of the genitalia of Galician A. flagellus lies between and upon the backs of the pair, with the ligulas visibly hugging the mate's body, a position resembling that of copulatory English A. lusitanicus in Davies' (1987) Figure 3B.

The Galician Arion flagellus is very like the Portuguese A. juligineus. The two species are almost the same length, both may or may not have dorsal bands, and the sole is white or yellowish. However, A. juligineus never has the greenish flush that is characteristic of A. flagellus. The genitalia are also very similar (in particular, the relative proportions of the epiphallus and the vas deferens are the same), except that the ligula of A. flagellus is circular whereas that of A. juligineus is shaped like an inverted V. The spermatophores are of equal length (20 mm), but that of A. juligineus widens towards the middle, whereas that of A. flagellus has a more uniform cross section; furthermore, the spermatophore crest of A. juligineus is not toothed or has less pronounced teeth than that of A. flagellus, and the spermatophore itself does not adopt the U-shape characteristic of A. flagellus. However, the two species differ mainly in their copulation. A. juligineus places its ligula on the flanks of the mate, whereas the Galician A. flagellus places its ligula upon its mate's back, gripping it; and the rotation of the pair that occurs in the copulation of the Portuguese A. juligineus is not performed by the A. flagellus of Galicia (though according to Davies [1987], English specimens of both A. subfuscus and A. flagellus may slowly rotate when copulating).

Externally, the Galician Arion flagellus differs in color from the Portuguese A. lusitanicus, which when adult has a dark yellowish chestnut body with two dorsal bands and a sole that is dark gray or black peripherally and lighter centrally; the upper parts of juveniles may be greenish gray or black. Internally, the epiphallus of A. lusitanicus is the same length as the vas deferens, and the spermatophore is longer than in the Galician A. flagellus (40 mm vs. 20 mm). The two species also differ in their copulation behavior and the shape of the ligula.

The Portuguese Arion nobrei is much larger than the Galician A. flagellus, and is olive green or bronze colored. The sole is always black. The genitalia are much larger than in A. flagellus: the epiphallus measures 30–35 mm, and the spermatophore may exceed 65 mm.

The Galician Arion flagellus differs from the English and Belgian A. subfuscus in size. Internally, its epiphallus and vas deferens are twice as long as those of A. subfuscus.

The Galician Arion flagellus differs in both internal and external morphology from the English A. lusitanicus, which exceeds 100 mm in length and is black or brown, with a sole of the same color. The epiphallus of the English A. lusitanicus is the same length as the vas deferens (both 18–20 mm), the ligula is elliptical, and the spermatophore is longer than that of A. flagellus and has a different shape.

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LITERATURE CITED


