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Bicephaly in *Salamandra salamandra* larvae

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ABNORMALITIES occur frequently in wild populations of amphibian and reptiles (e.g., Matz, 1998; Meyer-Rochow & Asahima, 1988; Worthington, 1974). Polymelia (presence of supernumerary limbs) or polydactyly (presence of supernumerary digits) are the most common alterations and have been reported frequently in the herpetological literature (e.g., Johnson *et al*., 2001; Recuero & Campos Asenjo, 2003; Sealander, 1944). Reports on bicephaly are, however, more scarce.

Bicephaly, in general terms, refers to the presence of two heads in a single individual. It has been documented occurring naturally in mammals, including humans (e.g., Wu, 2002), and reptiles (e.g., lizards [e.g., Pleticha, 1968], turtles [Diong *et al.,* 2003], geckos [Holfert, 1999]), being specially frequent in snakes (e.g., Belluomini, 1959; Da Cunha, 1968; De Lema, 1982, 1994; Hoser & Gibbons, 2003; Khaire & Khaire, 1984; Maryan, 2001; Mitchell & Fieg, 1996; Oros *et al*., 1997). Bicephaly, however, is not very common in amphibians. To our knowledge, it has only been documented in three anuran larvae (Dragoiu & Busnitza 1927; Lebedinsky, 1921; Loyez 1897) and in the Golden-striped salamander (Pereira & Rocha, 2004).

The term 'bicephaly' is used to describe a broad spectrum of developmental alterations. Different abnormalities, from the duplication of some structures of the head to the ocurrence of Siamese or co-joined twins, give rise to bicephalic individuals. Bicephaly may be the consequence of the incomplete separation of the zygote of identical twins (co-joined twins). Bicephalia may also occur by the terminal bifurcation of the axis of development of the embryo, the notochord, during the neurulation process. The notochord gets divided or forked, leading to two distinct axes and the formation of two neural plates and their neural

Figure 1. Craniofacial duplicated larva in *S. salamandra bejarae*. © D. Buckley.

Figure 2. Bicephalic co-joined twins in *S. salamandra gallaica.* © G. Velo-Antón.

crest cell derivates (Machin, 1993). Craniofacial duplication, is an unusual variant of bicephalia (e.g., Wu *et al*., 2002). In this case, cranial structures like eyes, mandibles and mouths get duplicated but the individual does not present two distinct heads or axis of development. In this note, we report one case of co-joined twins and one case of craniofacial duplication, in larvae from two different subspecies of the Fire salamander *Salamandra salamandra.*

The craniofacial duplicated larva was born from a *S. salamandra bejarae* female from the Central Iberian Peninsula. The female gave birth to 45 larvae, one of them presenting the abnormality (Figure 1). The larval body was fully developed, but presenting a duplication of the craniofacial structures (Fig. 1). All the structures were functional apparently, although the larva could not feed and died after two weeks in the laboratory.

The bicephalic co-joined twins were found in *S. salamandra gallaica* (Figure 2). A female from one of the Galician coast population (NW Iberian Peninsula) gave birth to 2 larvae, one of them presenting the abnormality. The bifurcation of the axis was manifest; one of the heads presented no eyes, although the gills and the two limbs were functional. The larva could not move easily, and fed normally through one of the head, presenting, however, a slower rate of development than its siblings.

It has been shown that polydactyly and polymelia are related, in some cases, to the presence of parasites within the individuals (e.g., Johnson *et al*., 2001; Sessions & Ruth, 1990). In the cases we present, however, the abnormalities presumably involve the disruption of the genetic and developmental pathways during the early development of the individual and during the neurulation process. The genetic cascades involved in the development of the head and craniofacial structures begin now to be well understood (e.g., Glinka *et al*., 1998; Nie, 2005) and the report of such examples of malformations can shed some light on the developmental process underlying them, and may also help to explain why this kind of abnormalities seems to be more frequent in some taxa (e.g., snakes) than in others.

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