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# A review of twinning in lizards and a report of Veiled Chameleon (*Chamaeleo calyptratus*) twin births

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Although twins in reptiles are considered rare, cases of twins have been reported in several orders like Crocodilia (Platt et al., 2011) and Squamata (Rothschild et al., 2012; Dieckmann et al., 2014; Nečas et al., 2020), and especially in Testudines (Yntema, 1970; Louro and Pereira, 2009; Piovano et al., 2011). Twins in lizards have been observed mainly in captivity. However, the rate of twinning in this group of reptiles could be underestimated, both in captivity and nature (Nečas et al., 2020). Underestimation may be due to the difficulty of identifying twins in egg clutches, especially in species with large eggs clutches or incubation of a large number of eggs at the same time. Regarding the causes of twinning, scientific articles on wild and captive cases hypothesise aberrant incubation conditions, such as atypical temperatures and humidity, infections, inbreeding or genetic mutations (especially in conjoined twins). (Dodd, 1988; Martinez Silvestre and Barrio-Amoros, 2018). Cases of conjoined twins in parthenogenetic females have previously been reported (d'A. Bellairs, 1965; Darevsky, 1966; Kearney and Shine, 2004) and in *Darevskia armeniaca* (Méhely, 1909), conjoined twins in parthenogenetic females were higher than normal twins (2.9% vs 1.5%) (Darevsky, 1966). Studies that have addressed the topic in reptiles (Darevsky, 1966; Kearney and Shine, 2004) did, however, not provide further explanations for the origin of the seemingly higher incidence of parthenogenic twins.

Chameleons are widespread among reptile hobbyists and probably for this reason several records of twins and conjoined twins have been reported (Nečas et al., 2020). On 16 March 2022, hatching of two twin pairs of Veiled Chameleons, *Chamaeleo calyptratus* Duméril and Duméril, 1851, was observed at the Riga Zoo (Latvia) (Fig. 1). The animals (one male and one female in each egg) were smaller in weight and length than any of their hatched siblings from a total of 85 incubated eggs (48 hatched). All four chameleons were active and feeding normally after hatching. One of them died at the age of two months (unknown causes) and three of them were still alive in February 2023 (Table 1). The twins were part of the second generation of *C. calyptratus* hatched

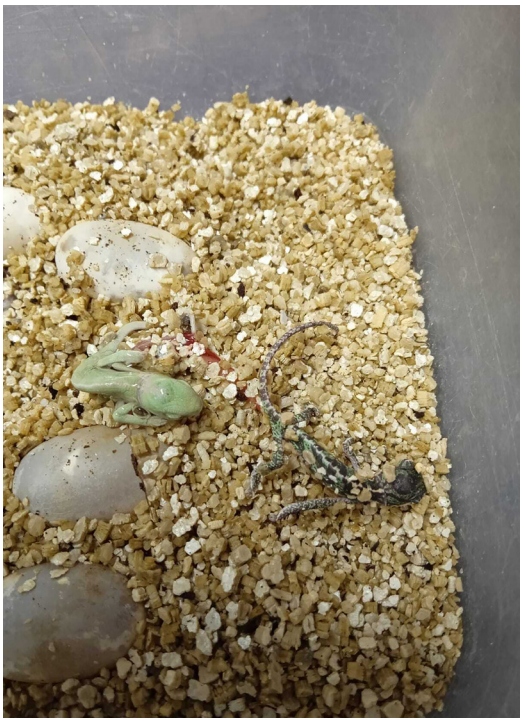

**Figure 1.** One of the twin pairs of Veiled Chameleons, *Chamaeleo calyptratus*, hatched at the Riga Zoo facility (16 March 2022). Photograph by Rasa Strūģe.

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**Table 1.** Cases of twins in lizards found in literature review. The survival rate concerns adult animals or animals alive at the date of the source publication. In bold are cases that concern the eggs or offspring of wild-born animals, with *Darevskia armenica* comprising an *in situ* observation. * Indicates death of the animal before hatching, [A] as mentioned in Nečas et al. (2020), [B] as mentioned in Mendyk (2007).

| Species | Twins' eggs (Total eggs) | Twins (number of hatched individuals) | Twin condition at hatching | | Survival rate | Source |
|---|---|---|---|---|---|---|
| | | | Alive | Dead | | |
| Family Agamidae | | | | | | |
| *Agama agama* | 1 | 2 | – | 2* | 0% | Carpenter and Yoshida (1967) |
| *Hydrosaurus pustulatus* | 1 (4) | 2 | 2 | – | NA | Hartdegen and Bayless (1999) |
| *Pogona vitticeps* | 1 (17) | 2 | 2 | – | NA | Hartdegen and Bayless (1999) |
| *Uromastyx geyri* | 1 (8) | 2 | – | 2 | 0% | Radovanovic (2020) |
| Family Chamaeleonidae | | | | | | |
| ***Calumma parsonii parsonii*** | 2 (60) | 4 | – | 4* | 0% | Durbin[A] |
| *Chamaeleo calyptratus* | 2 (85) | 4 | 4 | – | 75% | Our study |
| *Chamaeleo calyptratus* | 1 | 3 | NA | NA | NA | Monge[A] |
| *Chamaeleo calyptratus* | 1 | 2 | NA | NA | NA | Nečas (1999) |
| *Chamaeleo calyptratus* | 1 | 4 | – | 4* | 0% | Prokopiev[A] |
| *Chamaeleo calyptratus* | 1 | 3 | – | 3* | 0% | Prokopiev[A] |
| *Chamaeleo calyptratus* | 1 | 2 | 2 | – | NA | World of Reptiles[A] |
| *Furcifer pardalis* | 1 | 2 | 2 | – | 50% | Bowen[A] |
| *Furcifer pardalis* | 1 | 2 | 2 | – | 0% | Bowen[A] |
| *Furcifer pardalis* | 1 | 2 | 2 | – | NA | Clarkson (2005) |
| *Furcifer pardalis* | 1 | 1 | NA | NA | NA | Chameleon house[A] |
| *Furcifer pardalis* | 1 (24) | 3 | 2 | 1 | 0% | Eckhardt (2018) |
| *Furcifer pardalis* | 2 | 4 | NA | NA | NA | Manchen (1994) |
| *Furcifer pardalis* | 2 (20) | 4 | 4 | – | 100% | Pawlik[A] |
| *Trioceros jacksonii* | 1 | 2 | – | 2* | 0% | Manchen (1994) |
| *Trioceros j. xantholophus* | 1 (32) | 1 | 2 | – | 0% | Garcia[A] |
| ***Trioceros j. xantholophus*** | 1 | 2 | NA | NA | NA | Nečas (1999) |
| *Trioceros laterispinis* | 1 | 2 | 2 | – | 100% | Van Overbeke[A] |
| *Trioceros quadricornis* | 1 | 2 | NA | NA | NA | Duncan[A] |
| Family Scincidae | | | | | | |
| ***Plestiodon septentrionalis*** | 1 (18) | 2 | NA | NA | NA | Somma (1985) |
| Family Varanidae | | | | | | |
| *Varanus gouldii* | 1 (8) | 2 | 2 | – | NA | Hartdegen and Bayless (1999) |
| *Varanus indicus* | 1 | 2 | 2 | – | 0% | Speer and Bayless (2000) |
| *Varanus macraei* | 1 (5) | 2 | – | 2* | 0% | Mendyk (2007) |
| *Varanus mertensi* | 1 (6) | 2 | – | 2* | 0% | Eidenmüller and Stein (1991) |
| *Varanus mitchelli* | 1 (16) | 2 | 2 | – | NA | Kölner Zoo (2022) |
| *Varanus ornatus* | 1 | 2 | NA | NA | NA | Levinger[B] |
| *Varanus panoptes horni* | 1 (4) | 2 | 2 | – | NA | Bayless (1999) |
| *Varanus semiremex* | 1 | 2 | NA | NA | NA | Jackson (2005) |
| *Varanus varius* | 1 | 3 | NA | NA | NA | Krauss and Horn (2004) |

at Riga Zoo. The breeding pair was originally donated to the zoo by a private donor who bought them in a pet shop, reporting them as siblings.

Following the twin hatching observation, we carried out a bibliographic review by searching Google Scholar, following the methodology described in Di Marzio et

al. (2019). We performed two searches: one for studies on twins and another one for conjoined twins. We used specific key words ('twins' or 'conjoined twins' combined with 'lizards', 'Squamata', 'gecko', 'skink', 'monitor lizard', 'chameleon', and 'iguana'). We did not set a limit on publication year. We also reviewed the references in the retrieved articles and included those papers we considered relevant; resulting in a total of 89 papers of which we included 38 in the review. The review included studies published in several languages, as well as an online report that appeared during the review stage. Following the literature review, we compiled all cases of twins (Table 1) and conjoined twins (Table 2) as found for lizards. The results show a high number of twins in chameleons (Table 1), which includes a large number of observations from breeders obtained by Nečas et al. (2020), who collected data also from breeders' publicly available social media posts (both professional and hobbyists). It could be interesting to further investigate such online data, as comparable information may also be available on incidences of twinning among other lizard families.

During the bibliographic review, we tried to extract information about the origin of the animals (captive or wild-born) from included articles. However many papers, especially in cases of conjoined twins, do not report these data and for this reason further information was omitted. Still, we consider it important to also report on the partial data obtained from included sources. Reports of twins in lizards refer to hatchlings

**Table 2.** Cases of conjoined twins in lizards found in literature review. The survival rate concerns adult animals or animals alive at the date of the source publication. In bold are cases that concern eggs or offspring of wild-born animals. ** Indicates a lack of data on survival, [A] as mentioned in Rothschild et al. (2012), [B] as mentioned in Nečas et al. (2020).

| Species | Twins' eggs (Total eggs) | Twins (number of hatched individuals) | Conjoined twins' condition at hatching | | Survival rate[#] | Source |
|---|---|---|---|---|---|---|
| | | | Alive | Dead | | |
| Family Agamidae | | | | | | |
| *Agama agama* | 1 | 2* | – | thoracopagus | 0% | Carpenter and Yoshida (1967) |
| *Pogona vitticeps* | NA | NA | bicephalic | – | 0% | Förther (2002) |
| Family Anguidae | | | | | | |
| *Anguis fragilis* | NA | NA | axial duplication** | | NA | Payen (1995) |
| *Anguis fragilis* | – | 2 | 1 craniopagus; 1 conjoined** | | NA | Günther and Völkl (1996)[A] |
| *Anguis fragilis* | NA | NA | bicephalic | – | NA | Lessona (1877)[A] |
| *Anguis fragilis* | – | – | bicephalic | – | NA | Mazza (1892) [A] |
| *Anguis fragilis* | NA | NA | craniopagus** | | NA | Cantoni (1921)[A] |
| *Anguis fragilis* | NA | NA | craniopagus** | | NA | Reichenbach-Klinke and Elkan (1965)[A] |
| *Anguis fragilis* | NA | NA | craniopagus** | | NA | Riches (1955)[A] |
| Family Chamaeleonidae | | | | | | |
| *Chamaeleo calyptratus* | 1 | 1 | ischiopagus | – | NA | FlChams[B] |
| *Furcifer pardalis* | 1 | 1* | – | conjoined | 0% | Gibbs[B] |
| *Furcifer pardalis* | 1 | 3 * | – | conjoined | 0% | Roth[B] |
| *Trioceros quadricornis* | 1 | 1 | – | thoracopagus | 0% | Duncan[B] |
| Family Diplodactylidae | | | | | | |
| *Rhacodactylus auriculatus* | 1 | 1 | – | bicephalic | 0% | Holfert (1999) |
| *Rhacodactylus auriculatus* | – | – | bicephalic** | | NA | Rösler (2000)[A] |
| *Strophurus s. spinigerus* | NA | NA | bicephalic** | | NA | Rösler (2000)[A] |
| Family Gekkonidae | | | | | | |
| *Crossobamon eversmanni* | NA | 1* | – | thoracopagus | 0% | Rösler (1979) |

**Table 2.** Continued.

| Species | Twins' eggs (Total eggs) | Twins (number of hatched individuals) | Conjoined twins' condition at hatching | | Survival rate[#] | Source |
|---|---|---|---|---|---|---|
| | | | Alive | Dead | | |
| *Hemidactylus frenatus* | NA | NA | bicephalic** | – | NA | Payen (1995)[A] |
| *Hemidactylus turcicus* | NA | NA | bicephalic** | – | NA | Payen (1995)[A] |
| *Heteronotia binoei* | 2 (310) | 4 | thoracopagus | – | 0% | Kearney and Shine (2004) |
| *Phelsuma kochi* | NA | NA | craniopagus** | – | NA | Tytle et al. (1984)[A] |
| *Phelsuma madagascariensis* | NA | NA | craniopagus | – | NA | Payen (1995)[A] |
| *Phelsuma madagascariensis* | NA | NA | conjoined** | – | NA | Streckenbach (1979)[A] |
| Family Lacertidae | | | | | | |
| ***Darevskia armeniaca*** | 8 | 8 | bicephalic | – | NA | Darevsky (1966) |
| *Darevskia armeniaca* | NA | NA | bicephalic** | – | NA | Payen (1995)[A] |
| *Lacerta agilis* | NA | NA | – | thoracopagus | 0% | Andersen (1930) |
| *Lacerta agilis* | 1 | 1* | – | craniophagus | 0% | d'A. Bellairs (1965) |
| *Lacerta agilis* | NA | NA | bicephalic** | – | NA | Pleticha (1968)[A] |
| *Lacerta viridis* | NA | NA | conjoined** | – | NA | Klaussner (1890)[A] |
| *Lacerta viridis* | NA | NA | bicephalic** | – | NA | Silvestri (1892)[A] |
| ***Podarcis muralis*** | NA | NA | bicephalic | – | NA | Mahnert (1984)[A] |
| *Podarcis muralis* | NA | NA | bicephalic | – | NA | Martins d'Alte (1937)[A] |
| *Podarcis muralis* | NA | NA | craniopagus | – | NA | Payen (1995)[A] |
| ***Podarcis siculus*** | 1 | 1 | bicephalic | – | 0% | Insacco and Spadola (2009) |
| *Timon lepidus* | NA | NA | conjoined** | – | NA | Tur (1903)[A] |
| ***Zootoca vivipara*** | 1 | 1* | bicephalic | – | 0% | Ortiz-González (2018) |
| *Zootoca vivipara* | NA | NA | bicephalic | – | NA | Payen (1995)[A] |
| Family Phrynosomatinae | | | | | | |
| *Sceloporus cyanogenys* | NA | NA | incomplete conjoined twins | – | 0% | Köhler (1992)[A] |
| Family Scincidae | | | | | | |
| *Egernia striolata* | NA | NA | bicephalic** | – | NA | Matz (1989)[A] |
| *Eutropis multifasciata* | NA | NA | conjoined** | – | NA | Tur (1904)[A] |
| *Tiliqua scincoides* | 1 (8) | 1* | – | craniophagus | 0% | Willis (1932) |
| *Tiliqua rugosus* | NA | NA | thoracopagus | – | NA | Glauert (1947) |
| *Tiliqua rugosus* | 1 | NA | bicephalic** | – | NA | Matz (1989)[A] |
| ***Trachylepis striata*** | 1 | 1 | bicephalic | – | 0% | Broadley (1975) |
| ***Trachylepis striata*** | 1 | 1 | bicephalic | – | 0% | Broadley & Findlay (1972) |
| Family Sphaerodactylidae | | | | | | |
| ***Gonatodes albogularis*** | 1 | 1 | bicephalic | – | NA | Martinez Silvestre and Barrio-Amoros (2018) |
| Family Varanidae | | | | | | |
| *Varanus kordensis X Varanus prasinus* | 3 | 1 | bicephalic | – | 0% | Jacobs (2002) |
| *Varanus melinus* | 1 (9) | 2 | – | cephalopagus | 0% | Ziegler et al. (2010) |
| *Varanus varius* | NA | NA | anterior axial bifurcation** | – | NA | Payen (1995)[A] |

in captivity, with the exception of one in-situ report (*Darevskia armeniaca*; Darevsky, 1966). In six of the 38 assessed reports, the authors collected eggs from wild nests which were incubated in captivity (*Iguana iguana*; Martínez-Caballero et al., 2017), or collected wild-born pregnant females (*Calumma parsonii*; *Gallotia bravoana*; *Lacerta agilis*; *Plestiodon septentrionalis*; *Trioceros jacksonii*) (see Langford, 1985; Somma, 1985; Hernandez-Divers et al., 2003; Nečas et al., 2020).

The lack of observations of twins in the wild is almost certainly due to the difficulty of observing animals at the moment of hatching. Darevsky (1966) also report the case of conjoined *Darevskia armeniaca.* Although the origin (captive or wild-born) of most of the conjoined twins records was not available, the presence of six cases of conjoined wild-born twins in five species (*Gonatodes albogularis*; *Podarcis muralis*; *Podarcis siculus*; *Trachylepis striata*; *Zooteca vivipara*) (Broadley and Findlay, 1972; Broadley, 1975; Mahnert, 1984 (In: Rothschild et al., 2012); Insacco and Spadola, 2009; Martinez Silvestre and Barrio-Amoros, 2018; Ortiz-González, 2018), which were detected after hatching, suggests an underestimation of cases of twins in the wild.

We present the first systematic study on the occurrence of twin and conjoined twin cases across a wider range of lizard species. The prevalence of cases in captive animals (especially for twins) could be explained by the difficulties in detecting these cases in wild animals, in addition to inbreeding and problems related to artificial incubation (as suggested by several authors). Considering such difficulties, further studies in collaboration with breeders (while considering genetics and origin of the breeders) could provide new relevant data that is often disregarded or remains unrecorded in the scientific literature.

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