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**Studies on Anomalies
in Natural Populations of Amphibians**

**Untersuchungen zu Anomalien
in natürlichen Populationen von Amphibien**

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Commented glossary, terminology and synonymies of anomalies in natural populations of amphibians

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Abstract. To allow comparison of observations an unequivocal definition of terms is essential. While early scholars of amphibian anomalies already introduced specific terms and provided extensive definitions, some of these terms have changed their meaning over time, some are no longer used and others have been replaced more recently with alternative terms by some but not all authors. Most of the more recently published glossaries are rather narrow in their coverage, addressing primarily a limited set of skeletal anomalies, few provide synonyms and none of them discuss inconsistencies among different terminologies. To facilitate an understanding of the contributions in this volume and to facilitate comparison of publications in general, we provide an extensive glossary and synonymy of the terms used to describe external anomalies of amphibians. This includes colour and pattern anomalies, morphological anomalies, anomalies related to edema or tumours and anomalies of embryos. We discuss the inconsistencies among different terminologies and make recommendations for a future standardized use of terms. Our most important recommendation is to explicitly refer to a particular terminology and to describe the anomaly sufficiently to enable readers to understand what has been observed even if they are accustomed to using another terminology.

Keywords. Amphibia, anomalies, colour anomalies, skeletal anomalies, synonymies, terminology

Zusammenfassung. Eine eindeutige Definition von Begriffen ist für den Vergleich von Beobachtungen essentiell. Zwar haben bereits die ersten Forscher, die sich mit Anomalien in natürlichen Populationen von Amphibien beschäftigt haben, Begriffe zur Differenzierung verschiedener Typen von Anomalien eingeführt und dafür ausführliche Definitionen gegeben, jedoch haben einige Begriffe im Laufe der Zeit ihre Bedeutung geändert, andere fielen in Vergessenheit und wieder andere wurden von manchen, jedoch nicht allen neueren Autoren durch neue Begriffe ersetzt. Die meisten neueren publizierten Glossare sind im Umfang relativ beschränkt und beziehen sich vorwiegend auf eine kleine Auswahl von Skelettanomalien. Die meisten von ihnen gehen weder auf Synonyme noch auf unterschiedliche Definitionen von Begriffen durch verschiedene Autoren ein. Um das Verständnis der folgenden Beiträge in diesem Band und den Vergleich unterschiedlicher Publikationen zu erleichtern, stellen wir hier ein umfangreiches Glossar inklusive Synonyme zusammen. Dies umfasst Farb- und Musteranomalien, morphologische Anomalien, ödem- sowie tumorähnliche Anomalien und Anomalien von Embryonen. Wir diskutieren abweichende Verwendungen von Begriffen durch verschiedene Autoren und machen Vorschläge für eine konsistente Begriffsverwendung. Die wichtigste Empfehlung besteht darin, sich eindeutig auf eine bestimmte Terminologie zu beziehen und Beobachtungen ausführlich genug zu beschreiben, dass Leser die Art der Anomalie eindeutig identifizieren können, auch wenn sie eine andere Terminologie gewöhnt sind.

Schlagwörter. Amphibia, Anomalien, Farbanomalien, Skelettanomalien, Synonyme, Terminologie

1 Introduction

Natural populations of amphibians show a large diversity of deviations from the normal range of variation (HENLE et al. 2017a). Various terms have been used for such deviations. For deviations in morphology, for example, the terms malformation, deformity, abnormality or anomaly are used frequently. JOHNSON et al. (2001) suggested defining malformation as a “permanent structural defect resulting from abnormal development”, deformity as an “alteration in an organ or structure that originally formed correctly” and abnormality as “any gross deviation from the normal range in morphological variation”. These definitions were adopted by the US Fish & Wildlife Service (USFWS 2007) for the standard operating procedure of abnormal amphibian surveys in the USA.

Malformations and deformities as defined here are often difficult to distinguish without a detailed study of the case. For example, the absence of a digit (ectrodactyly) could either result from perturbations of ontogenesis (e.g. MARTIN & SIGNORET 1968, DEGIZZI et al. 2000) or from amputation after a normal ontogenesis (e.g. DEARLOVE & DRESDEN 1976, MUNEOKA et al. 1986). Some authors (e.g. McCALLUM & TRAUTH 2003) do not include injuries when reporting on abnormal amphibians. However, unless a wound is still open or bleeding, it is often very difficult to separate injuries from other anomalies, and in the field this is usually impossible (HENLE et al. 2017a). Therefore, we will consider both kinds of abnormal phenotypes under the general term “anomaly”, a practice that is followed by many authors. We also include all non-morphological deviations from the normal phenotype in this term.

The term “anomaly” is a relative one that has to do with the taxonomic status of specimens. What is an anomaly in a species or in a genus may not be so in another one. Thus, “albinism” is not an anomaly in *Proteus anguinus* or in other cavernicolous amphibians. White eggs are normal in species that deposit their eggs in places that are not exposed to sunlight, such as fast-running water, concealed sites on the ground or in vegetation above water (DUELLMAN & TRUEB 1986), but are an anomaly in species in which eggs are exposed to sunlight, such as most European species, the eggs of which are deposited in water (e.g. ROSTAND 1946, BENDER 1997). Likewise, black-eyed individuals are rare mutations in some species (HENLE et al. 2017a), whereas they are the normal condition in others (GLAW & VENCES 1997). In *Plethodon cinereus*, a red colour morph is frequent in some regions but very rare in others (LOTTER & SCOTT 1977) and thus might only classify as an anomaly in parts of the range.

Even gross morphological anomalies in a given species may be the normal condition in another one: thus, toads of the genus *Brachycephalus* have only two or three fingers and three or four toes, a condition, which would qualify as ectrodactyly in most other anuran genera. In some salamanders, toe morphology is highly variable

and it is difficult to set the limit between the range of normal and abnormal variation, e.g. in *Batrachuperus pinnichonii* (CHANG & BORING 1935), *Ambystoma maculatum* (WORTHINGTON 1974) and *Salamandrella keyserlingii* (BORKIN 1999, VERSHININ 2002). This variation may or may not be described by one of the terms included in the glossary below. Thus, the use of these terms does not necessarily imply an anomaly. However, we recommend using these terms only if such an implication is intended. In any case, one needs to be precise about whether one regards a particular phenotype as normal or abnormal.

It is impossible to provide a list of all possible anomalies in amphibians, as virtually all characters, in eggs, embryos (see overview by BANTLE et al. 1991), larvae and adults may be concerned. Some of these anomalies are very spectacular, such as polymely, and have attracted more attention than others (OUELLET 2000).

Early scholars of amphibian anomalies already provided extensive definitions of anomalies (e.g. GEOFFROY SAINT-HILAIRE 1832) and several more recent glossaries for amphibian anomalies also exist (e.g. DYRKACZ, 1981, TYLER 1989, METEYER 2000, METEYER et al. 2000, OUELLET 2000, GREEN & HARSHBARGER 2001, JOHNSON et al. 2001, 2010, VERSHININ 2002, 2015, SESSIONS 2003, USFWS 2007, LANNOO 2008, 2009, NEKRASOVA 2008). Most of them address and are (almost) limited to selected skeletal anomalies. The only relative comprehensive osteopathological glossary for amphibians and reptiles was published recently by ROTHSCHILD et al. (2012). DYRKACZ (1981) provided definitions for terms related to albinism and GREEN & HARSHBARGER (2001) for terms related to tumours.

Unfortunately, the terminology of amphibian anomalies is not always consistent among the different glossaries and among different scientists (BORKIN et al. 2012). Moreover, terminology has changed over time; some terms are no longer used, some have changed their meaning and others have been replaced with new terms by some but not all authors. Only BORKIN et al. (2012) and ROTHSCHILD et al. (2012) provided some synonomies and only the former authors discussed deviating definitions used by different authors. Therefore, it is not rare that the type of anomaly reported remains unclear even when a specific term was used.

To facilitate an understanding of the remaining publications in this issue, and to help identify the type of anomalies reported in the literature, we provide a commented glossary containing synonyms and explaining the different definitions given to a particular term. We also make recommendations towards future standardization of the use of terms. Our recommendations are guided by the following criteria: The recommended terms should reduce as much as possible any existing inconsistency and confusion. The terminology must be applicable in the field as in environmental monitoring it is not feasible to collect hundreds of individuals for detailed analyses in the lab. As a third criterion, with less weighing, we strived for an internally and etymologically consistent terminology.

We are aware that not everybody may agree with all of our recommendations. In any case, we strongly urge scientists to explicitly state which definition they followed and to describe the anomaly in sufficient details that readers are able to follow what they were referring to. An illustration of the observed anomalies using photographs should be considered, especially if they do not fit any of the given definitions very well. Anomalies may be rather complex, e.g. supernumerary limbs that are incompletely developed. For such cases we recommend only using the term applicable for the primary anomaly, in this instance polymely, and not to additionally call it ectromely. If one believes it to be relevant, one may rather provide a detailed description of the supernumerary limb.

2 Terms, definitions and synonyms

2.1 Anomalies of colouration and pattern

Terminology in this domain either follows external appearance or refer to the cells or pigments that were absent or modified. In most publications the presumed modified or absent chromatophore type was not verified by histological examination. However, inference from external colouration is not always a reliable indicator of the absence of a particular chromatophore type. Therefore, we recommend using a terminology based on the absence of pigments or chromatophore types only if histological examinations were made. Otherwise descriptive terms and statements, such as “black eyes”, “blackish frogs”, “blue frogs”, “erythristic”, “flavistic”, “golden frogs”, or “green frogs”, are preferable, ideally in combination with colour photographs (compare NISHIOKA 1977).

DYRKACZ (1981) provided a short glossary of terms related to albinism. RICHARD & NACE (1983) classified dark variants in amphibians according to the presence or absence of chromatophore types on different parts of the body.

Colouration and pattern and thus deviations from the normal phenotype are usually species-specific. Here we limit our glossary to types of colour and pattern anomalies that are not species-specific.



Fig. 1a: Albino-like white diurnal colouration of *Chiromantis xerampelina* is attained physiologically and thus not called albinism. Road South of Lower Sabie, Kruger NP, South Africa. Source: Wikipedia Commons. Photo: B. DUPONT.



Fig. 1b: Two large albinistic and a normal tadpole of *Bufo viridis*; albinistic individuals may be difficult to classify: individuals, such as the one on the left, are often called leucistic despite of them still having a few slightly pigmented spots; the middle one is closer to albinistic pinto with a few normal coloured dark spots and normal coloured hindlegs; Roßwag, Germany, September 1980. Photo: K. RIMPP.

Albinism | Partial or complete absence of integumentary pigmentation giving an individual a whitish, yellowish to golden or pinkish to reddish appearance (Figs. 1b, 6, 7, 11, 15, 16, 21 & 23b). Individuals with transparent skin are included, if the whole body is affected and if a golden, yellowish, reddish or whitish tone is present; however, cases in which only parts of the body show abnormal → translucent skin are never included despite partially lacking integumentary pigmentation. Likewise, individuals in which red colour replaces the normal yellow colour and blue frogs are generally not included in the term albinism. Sometimes albinism is used in a more restrictive sense as a synonym of → leucism, but most frequently it is either unspecified or used in the broader sense given here. Since albinism has been used in such a variable way, we recommend using a more specific term whenever possible. Terms for specific types of albinism are based either on external appearance [→ albinistic pinto, → complete albino, → erythrism (partim), → flavism, → leucism] or in relation to the presence/absence of pigments or chromatophores [→ amelanism, → axanthism (partim), → hypomelanism (partim), → hypopigmentation (partim)]. The terms of these two types of classifications cannot be fully matched because the absence of a particular chromatophore type will lead to different external appearance depending on the normal colouration of the species involved. Therefore, we strongly recommend using the terminology based on appearance unless histological examinations were made. Further subcategories of albinism are → partial albinism (only parts of the body affected) and → transient albinism (individuals increasingly acquire pigmentation during development). Some species can change physiologically to an albino-like white colouration but are not called albino (Fig. 1a)

Albinistic pinto | Normal pigmentation only present as small scattered spots (Fig. 1b); a subcategory of → albi-

nism. The term is not often used in the herpetological literature; instead, pinto individuals are often described under the more general term → albinism or, when normal pigmentation covers larger spots, → partial albinism

Albino | Usually a synonym of → true albino but sometimes additionally includes → leucism

Amelanism | Melanin or melanophores absent (a subcategory of → albinism). If absence is not verified histologically, individuals in which melanin or melanophores are reduced but not completely absent may be called amelanistic, but correctly speaking such cases fall into the category → hypomelanism. Sometimes amelanism is used as a synonym of → flavism (e.g. WILLIAMS et al. 2013) but this should be avoided because the absence of melanin does not necessarily result in yellowish individuals

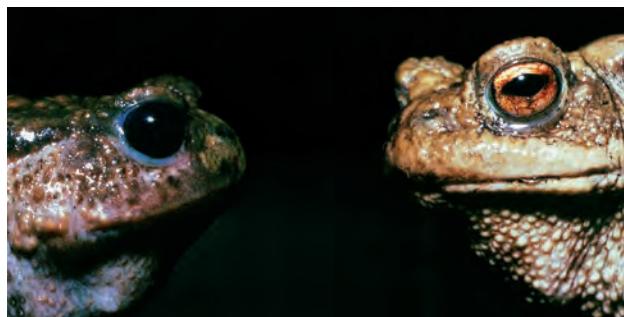


Fig. 2: Adult *Bufo bufo* with a black eye (left), due to a recessive mutation causing absence of iridophores as demonstrated by a crossing experiment, and normal phenotype (right); Carnelle Forest near Paris, France; 1983. Photo: A. DUBOIS.

Anomaly N | → Black eyed (Fig. 2)

Axanthism | Xanthophores or carotenoid vesicles in xanthophores absent. If the normal phenotype is green such individuals appear blue and are usually called → blue (frogs). In species with another normal colouration, it may be a subcategory of → albinism or may result in a species-specific abnormal colour pattern that is not reminiscent of albinism

Black eyed | Iris black coloured (Fig. 2); in some species, such as various dendrobatids (Fig. 9) and *Brachycephalus ephippium* (Fig. 12), black eye colouration is the normal phenotype (GLAW & VENCES 1997). Unilateral black-eyedness is a subcategory of → heterochromia

Blue frogs | Frogs with blue colouration (Fig. 5). The anomaly is due to a reduction or lack of xanthophores or their yellow pigments in species in which green is the normal phenotype. Thus, blue frogs are a special type of → axanthism but usually not included in the term → albinism. Notwithstanding, the term axanthism is sel-



Fig. 3: Blue as part of the normal colour pattern is rare in amphibians; in male *Aplastodiscus arildae* it is combined with transparency on hidden surfaces; Teresópolis, Brazil, 29.11.2004. Photo: K. HENLE.

dom applied to blue frogs. In a few frog species, such as *Aplastodiscus arildae* (Fig. 3), blue is part of the normal phenotype and male *Rana arvalis* (Fig. 4a) may turn blue during breeding

Complete albino | A subcategory of → albinism, in which all integumentary pigmentation is lacking (Fig. 6), including in the eyes (eyes that completely lack pigmentation may appear red due to blood vessels or may be vestigial; the body may appear pinkish due to blood vessels). Sometimes, the term is also used for individuals that lack all integumentary pigmentation but whose eyes have the normal colour. We recommend using the term → leucism for such cases and urge to use photos or descriptions of the eye colour to avoid confusion. A few cavernicolous species, notably *Proteus anguinus anguinus* (Fig. 7), are complete albinos in the normal phenotype

Depigmentation | Normal colouration of the body, or parts thereof, lost, usually due to exposure to chemicals or disease

Depigmentation of beaks and/or denticles | Tadpoles lacking pigmentation of the beak and/or denticles of the tooth rows, which are usually dark brown to black due to keratinization. Depigmentation may be due to pollution or infection by *Batrachochytrium dendrobatidis*, i.e., an anomaly, but also due to cold temperature, i.e., not an anomaly (reviewed by HENLE et al. 2017a)

Erythema | Reddening of the skin due to increased blood flow



Fig. 4a: *Rana arvalis*, blue colour is the normal phenotype for males in some regions during the breeding season; Elbe floodplain, Dessau, 19.4.2011. Photo: A. KÜNZELMANN.



Fig. 4b: *Rana arvalis*, normal phenotype outside the breeding season; Tschekalin, Russia, 20.7.2001. Photo: K. HENLE.

Erythrism | Red individuals. There are two types of abnormally red individuals: 1) xanthophores are replaced by erythrophores but the remaining pigmentation is

normal (Fig. 8); 2) integumentary pigmentation is absent except for erythrophores. The latter case but not the former is included in the term → albinism; DYRKACZ



Fig. 5a: Blue, an abnormal phenotype of *Pelophylax esculentus*; Braunschweig, Germany. Photo: A. MIRALLES.

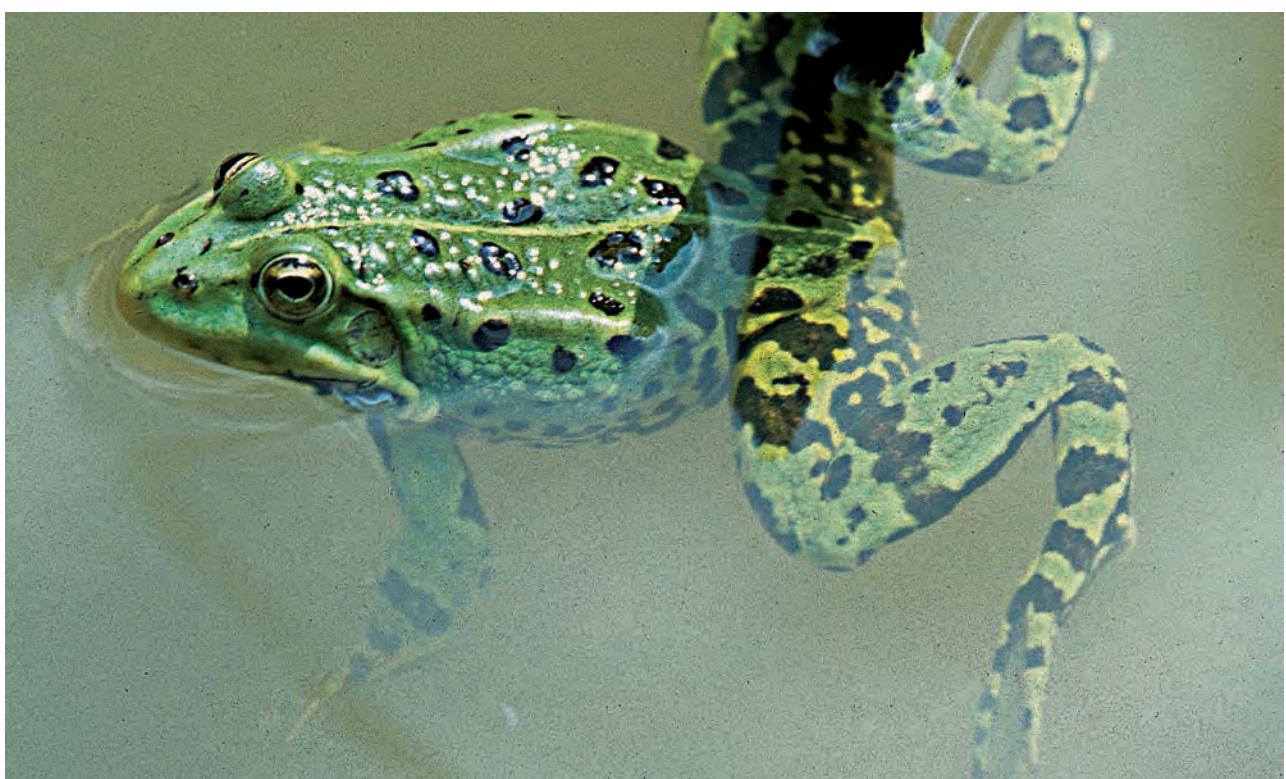


Fig. 5b: *Pelophylax esculentus* normal phenotype; Tschekalin, Oka, Russia, July 2001. Photo: K. HENLE.



Fig. 6: Normal phenotype and complete albino of *Xenopus laevis*. Source: Wikipedia Commons. Photo: Nashville Zoo.



Fig. 7: The normal phenotype of *Proteus a. anguinus* is complete albino; Baredine, Croatia, 23.6.2011. Photo: B. TRAPP.



Fig. 8a: *Salamandra salamandra*: normal colouration of an adult; Maourine pond, Toulouse, France, 30.10.1975. Source: Wikipedia Commons. Photo: D. DESCOUNENS.



Fig. 8b: *Salamandra salamandra*: erythristic adult, captive bred individual; Germany. Photo: B. TRAPP.



Fig. 9: *Oophaga pumilio*, a species in which red colour and black eyes are the normal phenotypes; Zoological Garden Wilhelma, Stuttgart. Photo: K. HENLE.

(1981) called this category partial albino with erythrophores, but this terminology is rarely used. Some species have a red colour as the normal phenotype (Fig. 9); these are usually not called erythristic, with the red eft of *Notophthalmus viridescens* (Fig. 10) and the red morph of *Plethodon cinereus* being exceptions



Fig. 10: In immature *Notophthalmus viridescens* red is the normal phenotype; North Fork Mountain, USA. Source: Wikipedia Commons. Photo: J. QUINN.

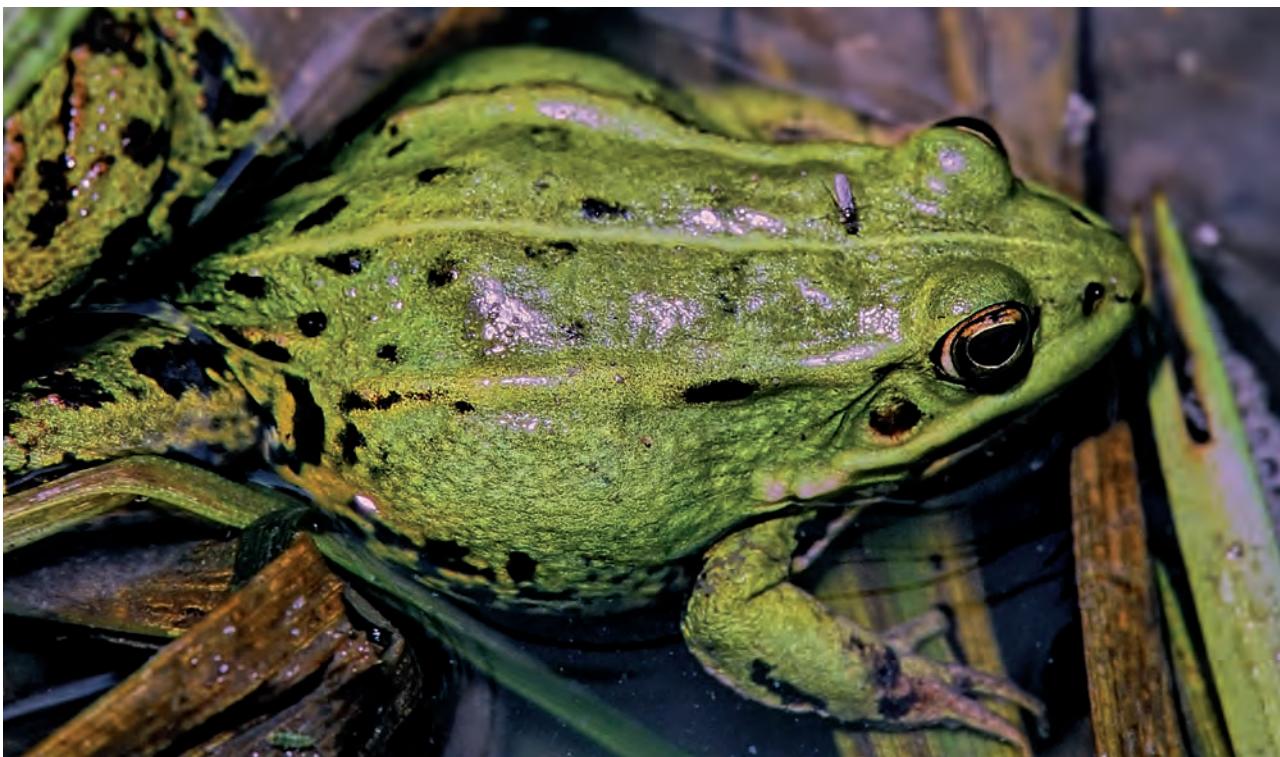


Fig. 11a: *Pelophylax esculentus*; normal phenotype; adult individual; Oka, Tschekalin, Russia, August 2007. Photo: K. HENLE.



Fig. 11b: *Pelophylax esculentus*; flavistic individual; Ballertasche, Germany. Photo: M. VENCES.

Flavism | A subcategory of → albinism that covers yellowish or golden-to-yellowish individuals (integumentary pigmentation absent except for xanthophores) (Fig. 11 & 23b). DYRKACZ (1981) referred to this category as

partial albino with xanthophores, but this terminology is rarely used. WILLIAMS et al. (2013) used → amelanism as a synonym of flavism but this should be avoided as amelanism does not necessarily result in yellowish in-

dividuals. Yellow or yellow-to-orange colouration of the body as normal phenotype appears in aposematically-coloured frogs (Fig. 12) and the males of some frog species, e.g. in the genus *Dendropsophus* (Fig. 13), turn completely yellow during the breeding season; usually, they are not called flavistic

Golden morphs | A subcategory of → flavism in which individuals appear golden (Fig. 23b)

Hemorrhage | Reddening due to bleeding (e.g. MILLER et al. 2011)

Heterochromia | The two eyes differ in their pigmentation (Fig. 14); sometimes used for unilateral → black-eyed individuals. As many different types of heterochromia exist, we recommend stating explicitly whether one eye was black; otherwise it is not possible to assign them to the black-eyed type of anomaly

Hyperpigmentation | Pigmentation (of body parts) increased in intensity compared to the normal phenotype; usually applied to cases that result from an increase in melanophores or melanin expansion; RICHARD & NACE (1983) called such individuals dark variants; if individuals are very dark but not completely black, they are called → melanoid



Fig. 12: *Brachycephalus ephippium*, a species in which black eyes and a yellowish-orange colour belong to the normal phenotype; Serra dos Orgãos National Park, Brazil, 1.12.2004. Photo: K. HENLE.



Fig. 14: Heterochromia in an adult female *Bufo bufo*; Glubochenskoye pond, Ural, Russia, June 2004. Photo: V. VERSHININ.



Fig. 13: *Dendropsophus minutus*, a species in which males turn yellow during the breeding season; near Ilhéus, Bahia state, Brazil, 23.8.2013. Photo: A. KWET.



Fig. 15: Hypomelanistic adult male *Triturus cristatus*. Those body parts that are normally black show a faint grey pattern; Nordstemmen, Germany. Source: MEYER (2009). Photo: S. MEYER.

Hypomelanism | Melanin or melanophores substantially reduced but present (Fig. 15) or melanophores permanently contracted; if the reduction is substantial, individuals may be called → albinistic

Hypopigmentation | Pigmentation (of body parts) reduced compared to normal individuals; if reduction is substantial, individuals are often called → albinistic

Incomplete albinism | Occasionally used instead of → leucism (e.g. SPADOLA & INSACCO 2010) but this should be avoided since all forms of albinism, except for → complete albinism, are incomplete albinism

Leucism | (Almost) all integumentary pigmentation absent but eyes pigmented (Fig. 1 & 16); in the literature sometimes confused with → flavism



Fig. 16: Leucistic *Epidalea calamita*, offspring from a leucistic male, Germany. Photo: B. TRAPP.

Melanism | A recent replacement term for → nigrinism; body or parts thereof completely black (Fig. 17); often used more broadly to include → melanoid individuals and → hyperpigmentation. If only parts of the body are affected, often called partial → melanism. A few species are completely black as normal phenotype, e.g. *Salamandra atra* (Fig. 18), and some, such as *Salamandrella keyserlingii* (HENLE et al. 2017a), may change colour physiologically and become completely black

Melanization | Individuals gain darker pigmentation over time from melanin synthesis, melanin expansion or an increase in melanophore numbers. Phenotypically, individuals may either become darker on larger parts of the body or dark spots may increase in size (VERSHININ 2002, 2015); may or may not be an abnormal condition

Melanoid | Very dark but not completely black individuals; a few species, e.g. *Salamandrella keyserlingii*, may change colour physiologically and become almost black (Fig. 19b)

Mid-dorsal stripe absent | Abnormal in species, in which the normal pattern generally includes a mid-dorsal stripe

Mid-dorsal stripe abnormal | Mid-dorsal stripe broken, bent or irregular in shape (Fig. 20)

Mid-dorsal stripe present | Abnormal in species in which a mid-dorsal stripe does not belong to the normal range of variation

Nigrinism | Old term for → melanism (e.g. KLUNZINGER 1903)

Novel colours | Parts of the body show colours that do not belong to the normal range of variation (e.g. yellow patches in *Bufo viridis*; HENLE et al. 2017a)

Partial albinism | The term is used inconsistently; most commonly, it is used for individuals, in which integumentary pigmentation is only absent on parts of the body (Fig. 21) but some authors also applied the term to individuals, in which melanophores are absent or strongly reduced but which have iridophores (then a synonym of → amelanism respectively → hypomelanism); others apply it to → flavistic individuals and KRONSHAGE & HILDMANN (1988) used the term instead of → transient albinism. To reduce ambiguity and confusion, we recommend restricting the term to the definition given by us and using other subcategories of → albinism for other types of reduced pigmentation; this also makes it consistent with the use of the term → partial melanism

Partial black | → Partial melanism



Fig. 17: Melanistic *Salamandra salamandra almanzoris*; born in captivity. Photo: U. SEIDEL.



Fig. 18: Black is the normal phenotype in *Salamandra atra*; adult near Bichlbach, Austria, 8.8.2014. Photo: A. GRIMM.

Partial melanism | Individuals in which parts of the body but not the entire body are completely black; the remaining body shows normal colouration; a subcategory of → melanism

Pattern lacking | → Unicolor

Periodic albinism | → Transient albinism

Semi-albino | Rarely used; if used, then either as a synonym of → flavism (e.g. CAPANNA 1967) or → leucism (e.g. SMALLCOMBE 1949, TUNNER 1979); we discourage the use of this term because this inconsistency may create confusion and established widely used terms are available for these two types of colour anomaly

Transient albinism | An anomaly in which the eggs are white but the tadpoles increasingly acquire pigmentation after hatching; in rare cases, pigmentation does not appear before metamorphosis; the light coloured tadpoles in early stages are called depigmented by some authors (VERSHININ 2015) but → depigmentation is usually applied to cases in which individuals initially were pigmented and later lost pigmentation. KRONSHAGE &



Fig. 19a: Colour variation in *Salamandrella keyserlingii*: normal phenotype; Nishni Angarsk, Lake Baikal, Russia, 26.7.2014. Photo: K. HENLE.



Fig. 19b: Colour variation in *Salamandrella keyserlingii*: almost black subadult taken in a very dark and cold place. This specimen looks like an abnormal melanoid individual but changed to normal colouration in a warmer environment. It also shows oligodactyly on the right hand; Ekaterinburg, Russia, 7.8.2007. Photo: V. VERSHININ.

HILDMANN (1988) called transient albinism → partial albinism, which is inconsistent with the usual definition of the latter term. Many amphibians that deposit their eggs at concealed sites have white eggs but the larvae or froglets that hatch from them are pigmented; these cases are usually not called transient albinism

Translucent | Pigmentation lacking and skin transparent (Figs. 3, 23b & 47) (NEKRASOVA 2008). In some species, notably in the family Centrolenidae, parts of the skin are translucent as the normal phenotype (Fig. 22)

Transparent | → Translucent

True albino | → Complete albino

Unicolor | Individuals that lack the dark or light pattern typical for the species, e.g. uniform green backs in the hylid *Acris crepitans* (GRAY 1995)

Xanthism | Yellowish individuals in which melanin is strongly reduced or absent (i.e., a synonym of → flavism, e.g. PALIS 1997, WILLIAMS et al. 2013)

2.2 Morphological anomalies

Several glossaries of skeletal anomalies have been published (e.g. GEOFFROY SAINT-HILAIRE 1832, TYLER 1989, METEYER 2000, METEYER et al. 2000, OUELLET 2000,



Fig. 20: Middorsal stripe abnormally bent, subadult *Pelophylax lessonae*; Tschekalin, Russia, 9.9.2002. Photo: K. HENLE.



Fig. 21a: Normal phenotype in an adult male *Triturus carnifex*, Stanjel, Slowenia, 24.2.2014. Photo: A. GRIMM.

JOHNSON et al. 2001, 2010, SESSSIONS 2003, USFWS 2007, LANNOO 2008, 2009, NEKRASOVA 2008, ROTHSCHILD et al. 2012). Most of them also provided definitions of a few non-skeletal morphological anomalies but no comprehensive glossary exists for non-skeletal morphological anomalies in amphibians. Moreover, recent glossaries often ignored the earlier terminology that already existed and most did not provide synonymies, thus creating considerable potential for confusion. Only BORKIN et al. (2012) discussed deviating use of some terms by different authors.



Fig. 21b: Partial albinism in *Triturus carnifex*; in this male, the normal colouration is maintained on the ventral parts of the body; thus, it is not a leucistic individual (but one might call it partial leucism); born in captivity. Photo: S. MEYER.

2.2.1 Anomalies of limbs

Acheiria | A synonym of → apody that is rarely used in studies of amphibian anomalies

Acheiropodia | A rarely used synonym of → apody in the herpetological literature (ROTHSCHILD et al. 2012); in the medical literature (e.g. IANAKIEV et al. 2001), it is used as a synonym of → hemimelia; to reduce confusion, we recommend using the historically established term, i.e. → apody



Fig. 22: Translucent skin is the normal phenotype in many centrolenid frogs, here *Hyalinobatrachium fleischmanni*; Guayabo, Costa Rica, 17.5.2003. Photo: A. KWET.



Fig. 23a: *Scinax fuscovarius*: Normal phenotype of an adult; Intervales National Park, Brazil, 6.11.2004. Photo: K. HENLE.



Fig. 23b: *Scinax fuscovarius*: abnormal transparency combined with flavism in a recently metamorphosed individual. Transparency is most obvious on the head and digits and most of the body is of a golden yellow colour. Such individuals are often called flavistic or are described under the generic term albinism. It is best, however, to refer to such individuals as "golden morph" and to provide a colour photo; Pro Mata Reserve, São Francisco do Sul, Brazil, 12.1.2001. Photo: A. KWET.

Adactyly | Absence of all digits (Fig. 32a; OUELLET 2000, ROTHSCILD et al. 2012); thus a specific form of → ectrodactyly; not defined in most recent glossaries of amphibian malformations; some authors use it as a synonym of → oligodactyly (e.g. JOHNSON et al. 2010)

Amely | One or several limbs completely lacking (Fig. 24; TYLER 1989, METEYER 2000, USFWS 2007, LANNOO 2008, 2009, NEKRASOVA 2008, JOHNSON et al. 2010, ROTHSCILD et al. 2012); a specific form of → ectromely; some recent glossaries (e.g. JOHNSON et al. 2001, SESSIONS 2003) define → ectromely in the same way as we define here amely; they were followed e.g. by ROMANSIC et al. (2011); presumably, this resulted from an inconsistency in the definition of ectromely by TYLER (1989) (see: ectromely); this definition of ectromely creates confusion as it deviates from historically established definitions that are still commonly used; therefore, we strongly recommend to keep the historically established definitions in which amely is treated as a subcategory of ectromely. Absence of limbs is the normal phenotype only in the order Gymnophiona (Fig. 25)

Ankylodactyly | A rarely used synonym of → syndactyly

Ankylosis | Various definitions exist: growing together (ROTHSCILD et al. 2012), stiffness of a joint (<http://en.wikipedia.org/wiki/Ankylosis>), fusion of two bones into one (<http://www.merriam-webster.com/dictionary/ankylosis>); not commonly used in studies of amphibian anomalies, and if so, mainly for the fusion of bones of a limb across a joint, sometimes combined with → taumely; we recommend limiting its use in the literature of anomalies of amphibians to the fusion of bones across a joint

Anomaly E | A dominant mutation in *Rana temporaria* that causes → clinodactyly, → ectrodactyly, → syndactyly, → ectromely and → brachymely; it may further involve → ectropolydactyly (Fig. 33; ROSTAND 1958, DUBOIS 1977)

Anomaly No | A dominant mutation in *Rana temporaria* that causes → symphalangy, → brachyphalangy, → clinodactyly and → hypophalangy but affected toes are different from those affected in → Anomaly Ro (DUBOIS 1977)

Anomaly P | A syndrome of anomalies characterized by → polydactyly in benign forms, either only in the hindlimbs or both in the hind- and forelimbs, whereas in its severe forms (Fig. 26) it includes → brachymely, inguinal → tumours, bony excrescences and even → polymely; it shows a postero-anterior gradient and a good, although not always perfect, bilateral symmetry (ROSTAND 1971, DUBOIS 2016)

Anomaly Ro | A dominant mutation in *Rana temporaria* that causes → symphalangy, → brachyphalangy, → clinodactyly and → hypophalangy but affected toes



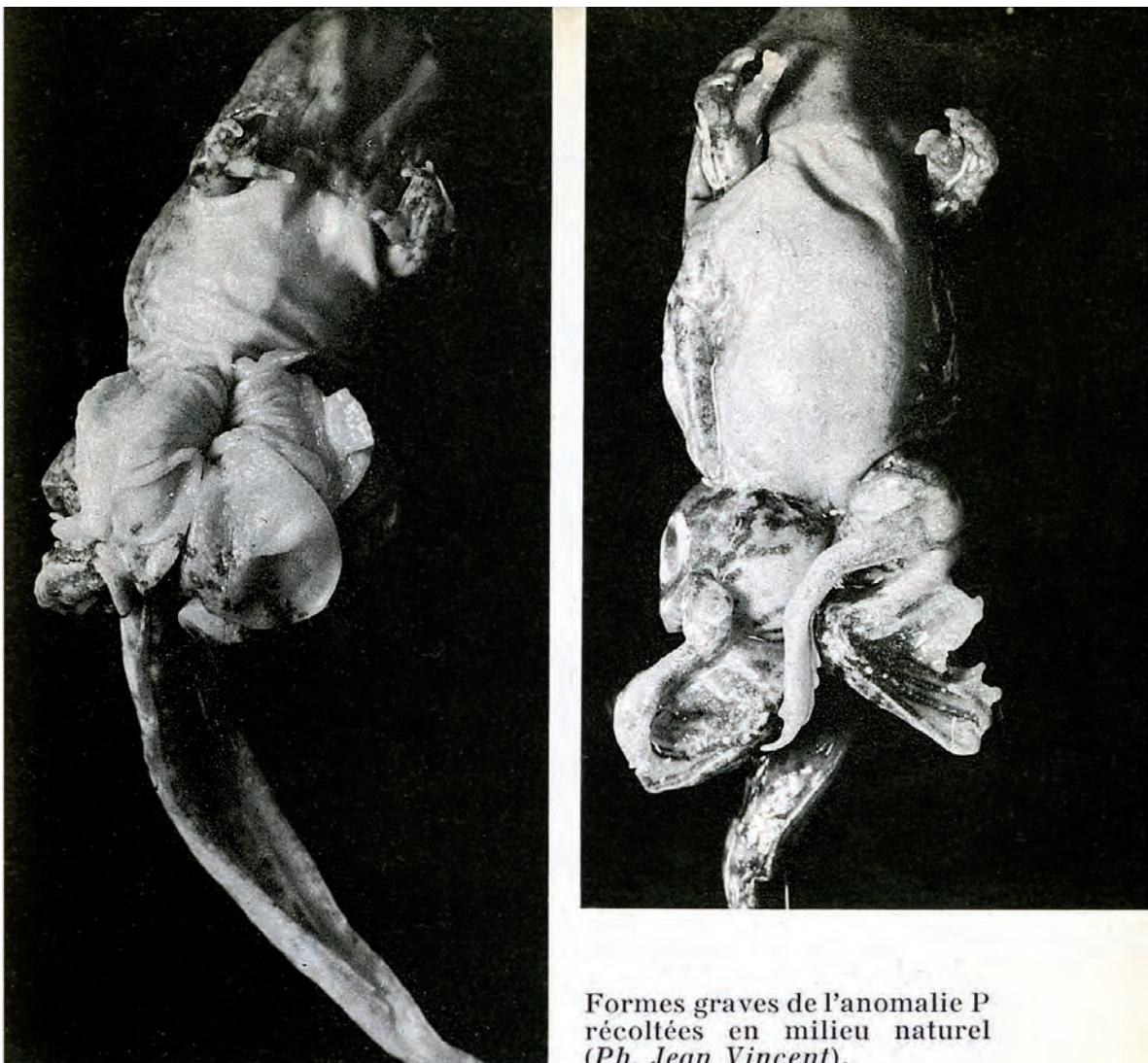
Fig. 24: Amely, a special form of ectromely, in *Rana arvalis*; Ekaterinburg, Russia, 13.7.2000. Photo: V. VERSHININ.



Fig. 25: Complete absence of limbs is the natural phenotype in the order Gymnophiona, here a female *Herpele squalostoma* with its litter; Yaoundé, Cameroon, 26.6.2012. Source: KOUETE et al. (2012). Photo: M.T. KOUETE.

are different from those affected in → Anomaly No (DUBOIS 1977)

Anteversion | A joint of (long) bones oriented in a forward direction (OUELLET 2000), leading to an abnormal positioning of the foot or hand (Figs. 27 & 28); thus,



Formes graves de l'anomalie P
récoltées en milieu naturel
(Ph. Jean Vincent).

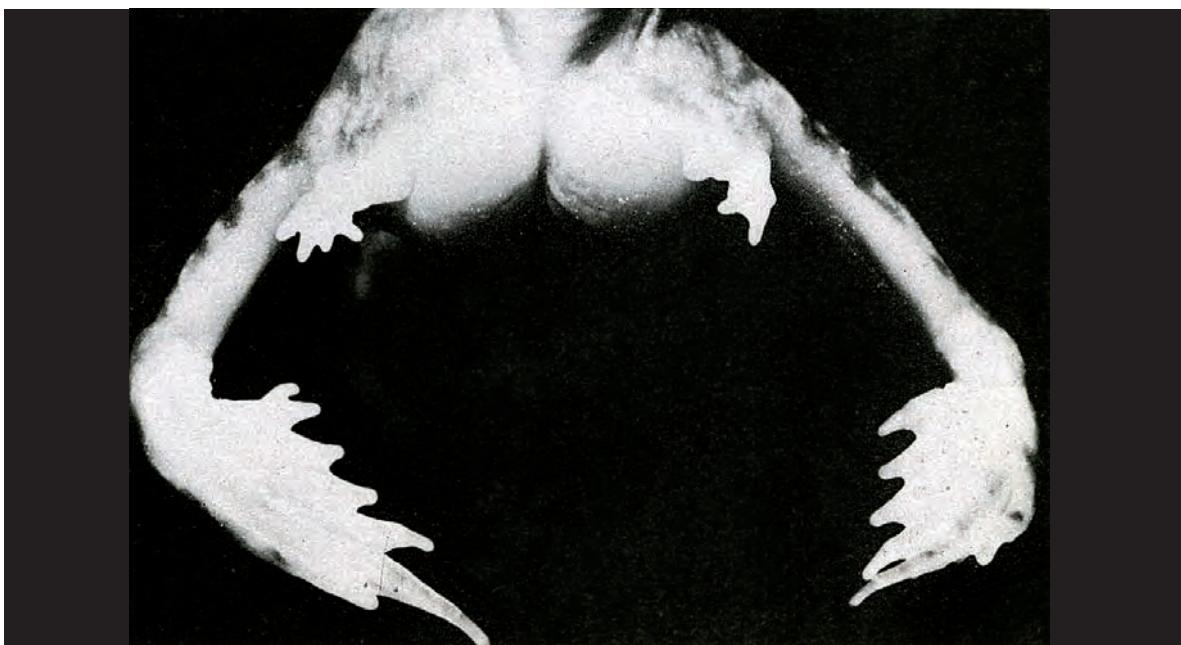


Fig. 26: Severe form of anomaly P in *Pelophylax* synkl. *esculentus*, France. The bottom figure shows particularly well the bilateral symmetry that is very frequently observed in anomaly P. Source: ROSTAND (1971).

anteversion is a specific form of → rotation (a term not used by OUELLET 2000). HOPPE (2005) applied anteversion more broadly, including → bony triangles, which is a specific form of → taumely; LANNOO (2008) defined anteversion very differently: as cork-screw shaped bones (which according to him usually is combined with taumely); based on the figure given by him, we assume that it is the same as what we call → taumely; because of these divergent and often unclear usages of the term, we discourage its further use, unless accompanied by a detailed description and then preferentially restricted to the definition given by OUELLET (2000)

Aphalangy | Absence of all phalanges of a digit (Figs. 19b & 32a,c); ROTHSCHILD et al. (2012) defined it as the absence of some phalanges of fingers, which is incorrect etymologically and for which another term exists: → hypophalangy; aphalangy and → oligodactyly may be used for the same type of anomaly, but the reference differs: the digit in the case of aphalangy and the hand or foot in the case of oligodactyly; both are subcategories of → ectrodactyly

Apody | Foot (hand) partially or completely missing (Fig. 29); a specific form of → ectromely

Arthrogryposis | It literally means curved joint, implying that it is fixed or stuck in the curved position (STAHELI et al. 2008); in the herpetological literature, it is occasionally used in the same sense, especially when combined with an underdeveloped musculature (in German → “Streichholzbeinchen”) (e.g. ZWART 1985)



Fig. 27: Anteversion combined with brachymely in a *Rana arvalis*; Ekaterinburg, Russia, 29.7.2001. Photo: V. VERSHININ.



Fig. 28: Anteversion of the right hindleg combined with a shortened foot (brachypody); unidentified species. Photo: USFWS.

and rarely also for → bent bones (LANNOO 2008); most frequently, however, the English term → stiff limbs is used instead of the technical term. We suggest restricting the use of the term to its original meaning

Bent bones | → Curved bones

Bifidy | A rarely used synonym of → schizodactyly (e.g. D'AMEN et al. 2006)

Bony bridge | → Bony triangle

Bony extension | → Bony projection

Bony projection | Digit-like microappendices projecting from the region of a (limb) bone (METEYER 2000); these microappendices can be small rudimentary elements of a supernumerary limb (i.e., → polymely) or rudiments of distal parts of an incomplete limb (→ hypomorphic limb); in the latter case, bony projection is either part of → ectromely (if the microappendix is



Fig. 29: Apody in *Indosylvirana temporalis*; Morningside, Sri Lanka, 2010. Photo: P. JANZEN.

a rudiment of the next distal bone, and thus should be classified as ectromely) or a form of → phocomely (if the microappendix originates from the region of a proximal long bone and is a complete or rudimentary digit) and thus should be scored as phocomely; → femoral projection is a subcategory of bony projection in which the microappendices originate from the region of the femur

Bony protuberance | → Bony projection

Bony triangle | → Bent long bone(s) forming a bony triangle or pyramid (Fig. 42; OUELLET 2000, ROHR et al. 2009), also called → bony bridge (e.g. METEYER 2000, METEYER et al. 2000, NEKRASOVA 2008); it is a subcategory of → taumely; JOHNSON et al. (2001, 2010) regarded it as the main form of → taumely and used the latter term when referring to bony triangles

Brachydactyly | Abnormally short digits; may be due to a reduced number (→ hypophalangy; Fig. 32b,d) or length (→ brachyphalangy) of phalanges or a combination thereof (Fig. 32b). A range of different definitions exists. METEYER (2000) restricted the definition to the one given here for brachyphalangy but did not include hypophalangy in any of the terms defined by her; however, USFWS (2007), which builds on her definitions, simply defined brachydactyly as short digits, which is equivalent to the definition given here; NEKRASOVA (2008) defined brachydactyly as we define hypophalangy. LANNOO (2008, 2009) defined brachydactyly as normal number of metatarsals but an abnormal number of phalanges, which would also include → schizodactyly and → polyphalangy (and thus → polydactyly according to our definition); this definition is discouraged as it creates considerable confusion of disparate patterns; besides, it is difficult to diagnose in the field whether the number of metatarsals is normal or not; VERSHININ (2015) defined brachydactyly as symmetrically shortened digits. ZAKS (2008) used the term → microdactyly as a synonym of brachydactyly; according to BORKIN et al. (2012), ZAKS also used the term → ectromely for the anomaly we define as brachydactyly, but this may be a lapsus calami; brachydactyly is a specific form of → ectrodactyly; note that several species, especially within Urodela, have a highly variable number of phalanges in their digits; thus brachydactyly is part of the normal range of variability in these species and one needs to know this normal range to decide whether a particular phenotype is abnormal or not; different authors may differ in their opinion for a particular species

Brachymely | Proportionally shortened limb (Figs. 27, 28 & 30), i.e., all long bones of the limbs are present but at least one is abnormally short (TYLER 1989, OUELLET 2000, KUPFERBERG et al. 2009, ROTHSCHILD et al. 2012, VERSHININ 2015); in the recent North American literature, and especially in the nation-wide surveys, the



Fig. 30: Brachymely in an adult *Rana dalmatina*; Waldsteinberg, Germany, May 2015. Photo: K. HENLE.



Fig. 31: Clinodactyly and oligodactyly of the right hindleg in a juvenile *Rana temporaria*; Tschekalin, Russia, 16.9.2013. Photo: K. HENLE.

term → hemimely is often used for this type of anomaly (e.g. METEYER et al. 2000, USFWS 2007, LANNOO 2008, NEKRASOVA 2008, WILLIAMS et al. 2008). While this definition is also commonly used in the literature on humans (e.g. COHN & BRIGHT 1999) it deviates from the historically established definitions that we provide here and that is widely used in the literature on anomalies in amphibians. As this recent change in the definition of hemimely can introduce considerable confusion, we discourage its use and recommend sticking to the original use of the term, which is also etymologically correct (“shortened limb”). Hemimely on the other hand means “half limb” and is thus inappropriate for a shortened limb; JOHNSON et al. (2001, 2010) defined brachymely as “abnormal shortness of one or more limbs”; while the definition is not explicit enough, comparing it with the definition they provided for ectromely and micromely suggests that they used it in the sense given here for brachymely; SESSIONS (2003) defined the term → micromely in the same way as we define brachymely; ROTHSCHILD et al. (2012) regarded the two terms as synonyms; here we regard micromely as a subcategory of brachymely in which all limb bones are shortened (as well as being proportionally smaller in diameter); some Russian authors apply the term ectrodactyly to the anomaly defined by us a brachymely (fide BORKIN et al. 2012); → brachypody is a further subcategory in which the tarsal or carpal bones are shortened



Fig. 32a: Specific forms of ectrodactyly: adactyly (right arm), adult *Bufo viridis*; Magnitogorsk, Russia, 8.5.1977.
Photo: V. VERSHININ.

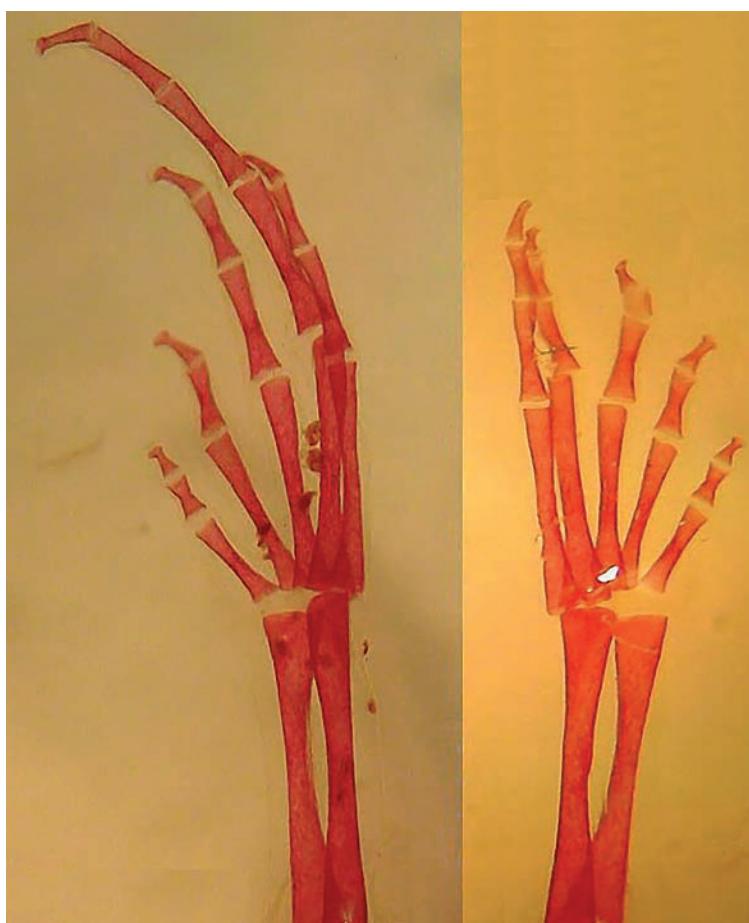


Fig. 32b: Specific forms of ectrodactyly: two sub-categories of brachydactyly: hypophalangy (digits 3 and 4) and brachyphalangy (digit 4) of the right foot compared to a normal foot (left); *Rana arvalis*; Ekaterinburg, Russia, 1.7.2000. Photo: V. VERSHININ.

Brachyphalangy | A bony element of a digit reduced in length (Fig. 32b), thus, a specific form of → brachydactyly; EATON-POOLE et al. (2003) also included missing proximal or middle phalanges in this category, which is inconsistent with the established use in the literature; we recommend sticking to its established use and to refer to such cases as → hypophalangy or to include them in the more inclusive term → brachydactyly

Brachypody | Hand or foot completely developed but some or all bones of the hand or foot shortened (Fig. 28). Not all authors consider this term and include such cases in the more inclusive term brachymely (VERSHININ 2015)

Carpalia abnormal | Bones of the hand fused, absent or additional bones present; often difficult to assess without radiographs



Fig. 32c: Specific forms of ectrodactyly: aphalangy (when referred to a single digit) or oligodactyly (when referred to the foot), juvenile *Rana temporaria*; Samarovo, Russia, 18.8.2012. Photo: K. HENLE.



Fig. 32d: Specific forms of ectrodactyly: brachydactyly, left hind limb of a *Rana arvalis*; Elizavet, Russia, 26.8.2010. Photo: V. VERSHININ.

Cartilaginous spike | A cartilaginous outgrowth from the end of a limb with missing distal bones (Fig. 35; SESSIONS 2003); only individuals that show ectromely can have this type of anomaly; thus we do not recommend counting it as an additional anomaly when totalling the number of anomalies or types of anomalies per individual

Clinodactyly | Curvature of digit caused by the presence of an intercalary little asymmetrical bone between two phalanges (Fig. 31). The definitions provided by TYLER (1989) and ROTHSCHILD et al. (2012) do not include the intercalary bone, thus also including → curvature of bones in this category; however, the explanation given by TYLER (1989) excludes such cases from clinodactyly. Note that when digits are split (→ schizodactyly) one part of the duplicated digit often bends outwards (Fig. 39b); therefore, and because the figure in TYLER (1989) can be misunderstood as a schizodactylous individual, some authors (e.g. VERSHININ 2002; note that since 2015 his group follows the definition given here – VERSHININ 2015) used the term clinodactyly for cases of schizodactyly; as this differs from the established use of schizodactyly and can create confusion, we discourage this usage of the term clinodactyly and recommend always referring to such cases as schizodactyly. Note that clino-

dactyly is difficult to diagnose in preserved specimens unless radiographs are used

Clinomely | Curvature of limb (FODOR & PUKY 2002); judging from a poorly reproduced photograph they seem to use the term as a synonym of → taumely. We strongly advice not to replace the established term taumely by clinomely. The term clinomely has rarely been used; an appropriate use could be as a technical term for → curved long bones as defined here

Curved long bones | Bones are curved; → torsion of limbs is sometimes used as a synonym for this type of anomaly but includes other types of anomalies as well. Cases in which the curvature involves a bending back of a bone on itself by $> 90^\circ$ or a misalignment with the rest of the bones are called → taumely; if the abnormal bones have the shape of a triangle or a pyramid, the terms → bony triangle or → bony bridge are often used interchangeably to describe this subcategory of → taumely (JOHNSON et al. 2001); we suggest using these latter terms to specify these types of bent bones or to describe the type of bending explicitly

Cutaneous fusion | → A band of skin crosses a joint of long limb bones restricting the motion of that limb; → skin webbing (METEYER 2000, LANNOO 2009) and → skin fold (VERSHININ 2015) are commonly used synonyms

Digits swollen | Thickening of the epidermis or the musculature of (parts of) a digit

Diplopody | Complete symmetrical duplication of the hand or foot including all digits (a specific form of → polypody)

Dipygus parasiticus | A specific form of → polymely in which the extra limb originates from the distal end of the pelvic girdle (GRIMME 1907); superficially, it may be misidentified as a retained tail; the recent literature rarely differentiates between the different types of polymely

Ectrodactyly | Partial or complete absence of one or more digits (Figs. 19b, 31-33) or digits shortened (GEOFROY SAINT-HILLAIRE 1832, TYLER 1989, OUELLET 2000). Some recent North American glossaries (e.g. METEYER et al. 2000, JOHNSON et al. 2001, SESSIONS 2003, USFWS 2007, LANNOO 2008, 2009) restricted the term to the complete absence of a digit (including the metatarsal bone), making it a synonym of → oligodactyly as defined here. This contradicts with most of the earlier literature and the definition given here that is also the common usage outside of North America. We recommend adhering to the established terminology as given here using → oligodactyly for a complete absence of at least one digit (e.g. TYLER 1989) and treating → adactyly (Fig. 32a), → oligodactyly (Fig. 32c) and → brachydactyly (Fig. 32b,d) and their subcategories as special cases

of ectrodactyly; ROTHSCHILD et al. (2012) recommended the spelling ectodactyly instead of ectrodactyly; we discourage this, as we never found this spelling in the literature on amphibian anomalies nor in the medical literature. Note that some species, e.g. *Proteus anguinus* (Fig. 7), have less than four fingers and five toes – the most common numbers in amphibians – as the normal phenotype

Ectromely | Partial or complete absence of a limb (Figs. 24, 29, 35) (TYLER 1979, NEKRASOVA 2008), except for cases where proximal bones are missing but the foot or digits are present (which is called → phocomely); ectromely thus includes → amely, → apody and → hemimely. A few recent authors (e.g. METEYER 2000, US-FWS 2007) include phocomely in the term ectromely but most authors do not; a few authors use the term more restrictively or differently: (1) for cases where the femur is present but the distal parts of the limb are missing (LANNOO 2008), which we define as → hemimely; (2) for cases where a limb is completely absent (e.g. HARRIS et al. 2001, SESSIONS 2003, PIHA et al. 2006, ROMANSIC et al. 2011), which we define as → amely. We recommend using the term amely for this specific subcategory as otherwise most readers will not realize that a specific subcategory is meant; moreover, etymologically amely is the correct term for a completely missing limb; note that while TYLER (1989) also defined ectromely as the complete absence of a limb, he explained that ectromely can also be partial and included → hemimely as a subcategory under ectromely; (3) ROTHSCHILD et al. (2012) recommended using the term “ectomely” and regarded “ectromely” as a synonym of → phocomely; to our knowledge ectromely has never been used as a syno-

nym of phocomely and the term ectomely is never used at all. They also included → adactly as a subcategory of ectromely, which again contradicts historical and current usage and thus should be avoided; (4) ZAKS (2008) used the term ectromely for what we call → brachydactyly (fide BORKIN et al. 2012)

Ectropolydactyly | One or several digits are absent while another digit is duplicated on the same hand or foot (Fig. 33; DUBOIS 1977); it may be part of the → anomaly E syndrome. Superficially the hand or foot may look normal in this type of anomaly; word combinations are not often used to define the co-occurrence of two different types of anomalies on the same body part; instead, most authors would call it → ectrodactyly plus → polydactyly

Femoral projection | A specific form of → bony projection in which the digit-like microappendages originate from the tissue of the femur; they may contain ossified elements (JOHNSON et al. 2001, KUPFERBERG et al. 2009); only those individuals exhibiting → ectromely, → phocomely, or → polymely can have this type of anomaly; thus we recommend not counting it as an additional anomaly when counting the number of anomalies per individual

Fracture of bone | Broken bone

Front leg(s) remaining covered by the opercular fold | The front legs of anurans usually remain covered by the opercular fold until the final stages of metamorphosis, when they break through the skin; in this rare anomaly one or both arms do not break through the skin (Fig. 34)



Fig. 33: Bilaterally symmetrical ectropolydactyly (anomaly E) in an adult female *Rana temporaria* (see DUBOIS 1977); the location of the metatarsal shows that toe I is duplicated; toe II is absent. At a glance, the individual might be scored as normal; Nointel near Paris, France, 1968. Photo: A. DUBOIS.

Gastromely | A supernumerary limb inserted at the venter between the front and hind legs (originating from the anterior part of the pelvis) (GEOFFROY SAINT-HILAIRE 1832); a specific form of → polymely; in the recent literature the term is rarely used

Hemimely | Complete loss of the distal half of a limb (Fig 35; TYLER 1989, OUELLET 2000, JOHNSON et al. 2001, 2010, SESSIONS 2003); hemimely is a subcategory of → ectromely. VERSHININ (2015) defined it as the absence of the distal parts of a limb, which may also include → apody; ROTHSCHILD et al. (2012) defined the term as “defective limbs, especially distal components”, which is rather ambiguous and could refer to a range of different types of anomalies. Some recent North American and Russian glossaries (e.g. METEYER 2000, USFWS 2007, LANNOO 2008, 2009, NEKRASOVA 2008) defined it as we define → brachymely here; this is inconsistent with all of the earlier herpetological literature and usage outside of North America but follows the definition of some authors working with other vertebrates (e.g. COHN & BRIGHT 1999). The term is also inconsistently defined in medicine: older influential lexica (e.g. DORNBLÜTH 1927) defined it as we do here; more recently, a wider definition is often used that includes → brachymely, but then usually only in combination with the affected bone. As the definition provided by us here is traditional, long-standing and well-established and still most frequently used in the literature on anomalies in amphibians, we

discourage recent deviations from the established use of the term as this only creates considerable confusion. Etymologically this is also preferable as “hemi” and “brachy” literally mean “half” and “short”, respectively; thus, applying hemimely to shortened limbs is etymologically incorrect

Hyperdactyly | A specific form of → polydactyly in which there is an entire extra digit present, with or without the duplication of a metacarpal or metatarsal bone (Fig. 37a); the term is rarely used (e.g. WEDDELING & GEIGER 2011). NEKRASOVA (2008) restricted the term polydactyly to this type of anomaly and ROTHSCHILD et al. (2012) regarded polydactyly and hyperdactyly as synonyms but the traditional use of the term polydactyly also includes incompletely duplicated digits

Hyperphalangy | Extra phalange present in a digit (FEDAK & HALL 2004, ROTHSCHILD et al. 2012); thus it is a synonym of → polyphalangy; sometimes, it is used more broadly as a synonym of → polydactyly (e.g. SWETT 1926); for a consistent terminology we suggest limiting it to cases in which additional phalanges are linearly arranged within a digit without the splitting of a digit, which is covered by the term → schizodactyly, and without a complete extra digit (→ polydactyly)

Hypodactyly | A synonym of → oligodactyly



Fig. 34: Right frontleg remaining covered by the opercular fold in a very large tadpole of *Bufo viridis*; Roßwag, Germany, September 1980. Photo: K. HENLE.



Fig. 35: Hemimely in a metamorph of *Bufo viridis* with short cartilaginous spike; September 1980, Roßwag, Germany, MNHN 1984.2326. Photo: H. STEINICKE.

Hypomorphic limb | The presence of one or more non-articulating microappendices from the soft tissue of a limb (SESSIONS 2003); contrary to the opinion of SESSIONS (2003) this is not diagnostic of amputation (see HENLE et al. 2017a). In the field, it may be difficult to separate from → bony projection. Also, ethymologically, the definition is incorrect as “hypomorphic” means that a limb is incompletely formed and will therefore include other types of limb anomalies, such as → ectromely, → phocomely and → brachymely, as well as their subcategories

Hypophalangy | One or several but not all bones of a digit are absent (Fig. 32b,d), i.e. a specific form of → brachydactyly, which in turn is a specific form of → ectrodactyly; it includes → monophalangy as a special case

Interdigital webbing | Webbing between digits in species that normally do not have such webbing

Joint dislocation | → Luxation

Limb hyperextension | Excessive or rigid flexure of a limb joint (JOHNSON et al. 2001); LANNOO et al. (2003) and LANNOO (2008) used the term for an anomaly where the legs are immobile and straight, with the anomaly being caused by the knee being locked in extension and the hip joint also being immobile; thus, his definition is a subcategory of → stiff limbs

Luxation | Displacement of the joint between two limb bones causing an abnormal articulation of bones; if dislocation is incomplete, it is called → subluxation

Melomely | → Polymely of the front limbs (Fig. 40) (Geoffroy Saint-Hilaire 1832); the term is rarely used in the recent literature

Meromely | Definitions vary; ROTHSCHILD et al. (2012) regarded it as a synonym of → adactyly, however, we could not find any publication that used it in that restrictive sense. In the medical literature and for other vertebrates often defined as partial absence of the limb skeleton (COHN & BRIGHT 1999); this definition includes → ectromely, → phocomely and → ectrodactyly and all subcategories thereof; further definitions exist. Therefore and as it has rarely, if at all, been used in the literature on anomalies in natural populations of amphibians, we recommend using other existing terms; if it is used, it must be explicitly defined

Metacarpal/metatarsal tubercle lacking | An anomaly only found in species that usually have a metacarpal or a metatarsal tubercle, respectively

Metatarsal tubercle abnormally enlarged | Metatarsal tubercle larger than within the normal range of variation

Microdactyly | ZAKS (2008) used it as a synonym of → brachydactyly

Micromely | Limbs complete but all elements proportionally smaller than normal (METEYER 2000, OUELLET 2000, USFWS 2007, NEKRASOVA 2008, LANNOO 2009). ROTHSCHILD et al. (2012) treated it as a synonym of → brachymely, which they defined as we do; JOHNSON et al. (2001, 2010) and SESSIONS (2003) defined micromely as “abnormal smallness of a limb”, which may or may not include brachymely as defined by us; SESSIONS (2003) did not include brachymely in his glossary and thus might have regarded both terms as synonyms; in contrast, JOHNSON et al. (2010) also provided a definition of brachymely: “shorter limb or limbs” and thus it is likely that they did not regard the terms as synonyms. In many publications, it remains unclear as to whether brachymely or micromely as we define these terms is what is actually meant; we recommend using both terms as defined here, thus regarding micromely as a specific form of → brachymely and describing the anomaly in sufficient detail to unequivocally identify the type of anomaly observed

Monodactyly | A special case of → oligodactyly, in which only one digit is present

Monophalangy | A special case of → hypophalangy, in which only one phalange is present

Nanomely | A rarely used synonym of → micromely (BORKIN et al. 2012, ROTHSCHILD et al. 2012)

Notomely | A special case of → polymely, in which the supernumerary limb originates from the dorsum

Oligodactyly | Less than the normal number of digits but at least one digit present (Figs. 19b, 31, 32c) (NEKRASOVA 2008, ROTHSCILD et al. 2012, VERSHININ 2015). TYLER (1989) is not explicit enough to know whether he regarded oligodactyly as a synonym of ectrodactyly or as a special case of it as we do; oligodactyly and → aphalangy may be used for the same type of anomaly, but the reference differs: the digit in the case of aphalangy and the hand or foot in the case of oligodactyly

Phocomely | An incomplete limb with a proximal bone missing but distal bones present (Fig. 36) (METEYER 2000, NEKRASOVA 2008, ROTHSCILD et al. 2012); often the foot (hand) or toes (fingers) are attached directly to the shoulder or the pelvic girdle; METEYER (2000) regarded this anomaly as a special case of → ectromely but most authors treat the two types of anomalies as separate categories; therefore, we recommend following the established use regarding them as separate categories; BACON et al. (2006) used phocomely for complete but malformed limbs, which is inconsistent with the usual definition of phocomely

Pleuromelophorus tetrachirus | A specific case of → melomely, with four arms; melomely in turn is a subcategory of → polymely; the term is rarely used in the recent literature

Pleuromelochirus tetrascelus | A specific case of → pygomely, with four hind legs; pygomely in turn is a subcategory of → polymely; the term is rarely used in the recent literature

Polydactyly | Duplication of digit(s) (Figs. 37 & 38) or parts thereof (Figs. 39a,b) (FISCHER 1977, TYLER 1989, JOHNSON et al. 2001, SESSIONS 2003); this definition includes → schizodactyly (Figs. 39a,b) in which only parts of a digit are duplicated, → synpolydactyly (Fig. 38) in which the proximal parts of the duplicated digit are fused, and → hyperdactyly, in which the whole digit is duplicated (Fig. 37). JOHNSON et al. (2010) defined polydactyly as “supernumerary digit(s)”, which presumably but not definitely includes schizodactyly. VERSHININ (2015) followed the definition given here but earlier publications of him and some other Russian authors used the term as a synonym of hyperdactyly (e.g. NEKRASOVA 2008); some authors (e.g. METEYER 2000, METEYER et al. 2000, LANNOO 2008, 2009, ROTHSCILD et al. 2012) and presumably OUELLET (2000) restricted the term polydactyly further to cases in which more than the normal number of metatarsal/metacarpal bones is present; ROTHSCILD et al. (2012) further regarded polydactyly and → hyperdactyly as synonyms but the definition of hyperdactyly generally does not include the presence of an additional metatarsal/metacarpal; they referred to a complete duplication of digits without an extra metatarsal/metacarpal bone as → polyphalangy, which also deviates from the commonly used definition of polyphalangy, which is used for linearly arranged duplicated

phalanges; → schizodactyly was not included in the definition of the above authors nor did they provide a term for this type of anomaly. Whether a metacarpal or metatarsal bone is duplicated is very difficult to assess in the field and therefore this distinction has rarely been made for field samples; therefore, and because the definition given by METEYER (2000) deviates from the more widely used definition, we recommend adhering to the traditional definition given here



Fig. 36: Phocomely – left tarsus attached to the femur – in a juvenile *Bufo bufo*; Sagra, Russia, 2002. Photo: V. VERSHININ.

Polymely | Duplication of a complete limb or parts thereof (if more than the digits are duplicated) (Figs. 40 & 41; GEOFFROY SAINT-HILAIRE 1832, TYLER 1989, JOHNSON et al. 2001, SESSIONS 2003, NEKRASOVA 2008, VERSHININ 2015); the definition includes → schizomely and → polypody as subcategories. METEYER (2000) provided a similar definition but excluded polypody; LANNOO (2008, 2009) went one step further and restricted the term to complete extra limbs. We suggest following the more widely used broader definition given here. In the early herpetological literature, but rarely in the recent one, the following terms and their subcategories were used to differentiate between the different types or the position of the supernumerary limb: → gastromely, → melomely, → notomely, → pygomely

Polyphalangy | An extra bone inserted into a digit without splitting the digit (i.e. in a linear arrangement). Vari-



Fig. 37: Polydactyly in *Pelophylax ridibundus*; Oka, Tschekalin, Russia, 12.8.2007. Photo: K. HENLE.



Fig. 38: Polydactyly, with proximal fusion of the duplicated fingers, in *Pelophylax esculentus*. Although one could call this anomaly polydactyly plus syndactyly or synpolydactyly, we recommend counting only the primary anomaly, in this case polydactyly; Seelenhofer Ried, Germany (compare MACHADO et al. 2010). Photo: C. MACHADO.



Fig. 39a: Schizodactyly, a specific form of polydactyly, in the right hind limb of a *Lissotriton vulgaris*; Ekaterinburg, 2002. Photo: V. VERSHININ.



Fig. 39b: Schizodactyly in the foot of an adult *Rana arvalis*. Note: the supernumerary toe bends away from the normal toe; although one could call it polydactyly plus clinodactyly we recommend not counting it as clinodactyly because the bending is a consequence of the primary anomaly schizodactyly; Kalinovsky forest park, Ekaterinburg, Russia, 19.7.2009. Photo: V. VERSHININ.

ous other definitions exist: NEKRASOVA (2008) included → schizodactyly as defined by us in her definition of polyphalangy and HALL (2005) applied the term to any extra phalanges, whether linearly arranged (i.e. polyphalangy in our definition) or with splitting (→ schizodactyly in our definition) or a complete duplication of digits (→ hyperdactyly in our definition); thus he used it as a synonym of → polydactyly. METEYER (2000) and METEYER et al. (2000) used the term for another type of → polydactyly, in which there is (are) extra digit(s) present without a duplication of the metatarsal bone(s); except for in the recent North American literature (e.g. McDANIEL et al. 2004), this definition is rarely applied in the literature on anomalies of amphibians (and very

difficult to apply in the field). The definition provided by ROTHSCHILD et al. (2012) is not very precise but presumably means the same as the definition provided by METEYER (2000). To reduce ambiguity, to make terminology consistent and in particular because the distinction between the different types of duplicated digits made by METEYER (2000) is difficult in the field and therefore has rarely been made for field samples, we recommend using the definition given here for → polyphalangy, → schizodactyly and → hyperdactyly if one can identify the nature of the duplication and otherwise using the more inclusive term → polydactyly

Polypody | A limb with one or more extra feet (hands) or parts thereof (JOHNSON et al. 2001, 2010, SESSIONS 2003) but more than the duplication of digits (Fig. 41); a specific form of → polymely

Pseudomely | VIZOTTO et al. (1977) used the term as a synonym of → polymely



Fig. 40: Melomely, a specific case of polymely in a captive offspring of *Dendrobates tinctorius*. Photo: S. KOEHLER.

Pygomely | A specific form of → polymely, in which the hind limb(s) are duplicated (Fig. 41)

Rotation (of limbs) | Limbs appear twisted and the foot (hand) is not flat with the surface; as defined here, this type of anomaly can either be caused by a distortion of the direction of the bone growth (→ curved bones) or an abnormal articulation of two bones (→ anteversion; Figs. 27 & 28); METEYER (2000) and NEKRASOVA (2008) restricted the term to the first case; a rotation of limbs is always combined with → stiff limbs

Schizodactyly | Forked digits (Figs. 39a,b); this is a specific form of → polydactyly; rarely called → bifid (e.g. D'AMEN et al. 2006). The definition given by NEKRASOVA (2008) for → polyphalangy includes schizodactyly but not our definition. Note that the supplementary phalanges often bent away from the base of the toe (Fig. 39b); therefore and because the figure of → clinodactyly in TYLER (1989) – but not his definition of it – is misleading, some authors (e.g. VERSHININ 2002) referred to cases of schizodactyly as clinodactyly. As incomplete duplication of a digit is the primary type of anomaly, we discourage this usage and recommend to call such cases schizodactyly to distinguish them from cases of → clinodactyly that do not involve the partial duplication of a digit. Since 2015 VERSHININ (2015) follows the definition given here

Schizomely | Completely duplicated limbs in which the proximal parts of the limbs are fused; thus it is a specific form of → polymely

Skin fold | A synonym of → cutaneous fusion (VERSHININ 2015)



Fig. 41: An unusual form of polypody, which is a specific form of polymely, in an adult female *Lissotriton vulgaris*; the two supernumerary feet show different degrees of duplication, the lower one would not be regarded as duplication of the foot but rather as a bony protuberance following the classification of METEYER (2000); Bayreuth, Germany, spring 2011. Photo: K. SZEPANSKI.

Skin webbing | A synonym of → cutaneous fusion (US-FWS 2007, NEKRASOVA 2008)

Spindly limbs | English term for → Streichholzbeinchen

Stiff limbs | Limbs are immovable; stiffness is linked to other anomalies of bones, such as → polymely (Fig. 39), → rotation of limbs (Figs. 27 & 28) or → taumely (Fig. 41), to → cutaneous fusion or the reduction of musculature; the latter is called → Streichholzbeinchen in the German amphibian husbandry literature

Streichholzbeinchen | The German term for → stiff limbs with degenerative musculature, giving the limbs a spindly appearance. This anomaly is called the fixed limb syndrome by KOVALENKO (2000). It is a subcategory of stiff limbs

Subluxation | Incomplete or partial → joint dislocation (OUELLET 2000)

Symmely | Partial or complete fusion of two limbs (PUKY & FODOR 2002, ROTHSCHILD et al. 2012). We only know this type of anomaly from supernumerary limbs that are partially fused with the normal limb, from *Bombina bombina* in Hungary (PUKY & FODOR 2002) and from a single individual of *Pelophylax esculentus* described by BRUCH (1864) – he called it → sympody – in which the hindlegs were fused at the level of the femur and not just the feet. In the case of the fusion of supernumerary limbs, the primary anomaly is polymely; therefore, we recommend counting such cases as polymely as opposed to listing them additionally as symmely. OUELLET (2000) and JOHNSON et al. (2010) provided a different definition for symmely: fusion of a limb or parts of a limb to a body part; we have not found any publication on anomalies in natural populations of amphibians that described such an anomaly; symmely is a specific expression of → synostosis

Symphalangy | Two phalanges of the same digit are fused (DUBOIS 1977); it is a subcategory of → syndactyly

Sympody | Only the distal parts of two limbs are fused (BRUCH 1864); a very rare type of anomaly; the individual described by BRUCH (1864), however, would rather classify as → symmely to which sympody belongs as a subcategory; sympody is a specific expression of → synostosis

Syndactyly | The partial or complete fusion of two or more digits due to failure of the soft tissue to break down between digits or due to the fusion of bones of different digits (TYLER 1989, OUELLET 2000, JOHNSON et al. 2001, 2010, SESSIONS 2003, USFWS 2007, LANNOO 2008, 2009, ROTHSCHILD et al. 2012, VERSHININ 2015), the latter being termed → symphalangy; syndactyly is a specific expression of → synostosis

Synostosis | Fusion of bones

Synpolydactyly | Duplication of digits, with digits fused by soft tissue or with proximal phalanges partially fused (Fig. 38; COHN & BRIGHT 1999); → schizodactyly is similar but the proximal phalanges are single rather than duplicated and fused; synpolydactyly is a subcategory of → polydactyly

Tarsalia abnormal | Bones of the foot are either fused or absent or additional bones are present

Taumely | Gross disturbance of the limb plan, whereby the misalignment of a long bone is more than 90° (Fig. 42; TYLER 1989, VERSHININ 2002, 2015). The degree to which the bone bends back may vary and some authors (e.g. GARDINER & HOPPE 1999) included any degree of bending back within the term taumely, whereas others (e.g. TYLER 1989, METEYER 2000, METEYER et al. 2000, JOHNSON et al. 2001) restricted it to the definition given here. We suggest including also cases with a lesser degree of bending if the bauplan of the limb is grossly disturbed. The abnormal bone may have the shape of a pyramid or triangle; such cases are often called → bony triangle or → bony bridge (e.g. METEYER et al. 2000); however, it is not entirely clear whether METEYER (2000) and JOHNSON et al. (2001) regarded bony triangles as a synonym or as a subcategory of taumely; we recommend the latter to separate these anomalies from other types of taumely; we further suggest calling slightly bent bones → curved bones to separate them from grossly misaligned bones



Fig. 42: Particularly grossly malformed left hindlimb that looks like a bony triangle, which is a special case of taumely. The malformation is, however, complex, since the tibia is either missing or completely synostosed with the femur and the foot is reduced in size and the number of digits; in such cases it is best to describe and provide a figure of the observed individual and not simply allocate them to a particular term of anomaly; juvenile *Rana arvalis*; Ekaterinburg, Russia, 5.8.2003. Photo: V. VERSHININ.

Toe pad swollen | Epidermis of toe pad thickened

Torsion of limbs | A synonym of → rotation of long limb elements

Triphalangy | A specific form of → oligodactyly, in which three digits are present (Fig. 19b)

Twisted limbs | A synonym of → rotation of limbs

2.2.2 Anomalies of the head, body or tail

Aglossia | Tongue absent (NEKRASOVA 2008)

Agnathia | Jaw completely missing (NEKRASOVA 2008)

Anadydimus | Two tails (WALLACH 2007)

Anal tube closed | Anal tube distally covered by skin

Anophthalmia | Eye(s) lacking (blindness) (Fig. 43; TYLER 1989, METEYER 2000, JOHNSON et al. 2001, SESSIONS 2003, USFWS 2007, NEKRASOVA 2008, LANNOO 2009, VERSHININ 2015); LANNOO (2008) called this type of anomaly microphthalmia, which was a lapsus calami; unilateral anophthalmia is sometimes called → cyclopia by Russian authors (e.g. ZAKS 2008, FAYZULIN 2011) but cyclopia usually is defined differently

Asyntaxia caudalis | Duplication of tail due to a failure of the anal fold to close; it is a specific expression of → anadydimus

Axial flexure | Torsion of the vertebral column

Axial incursion | → Axial flexure

Beak lacking keratinization | The jaw sheaths of the mouths in tadpoles are developed but not keratinized or the keratin was destroyed by pollution or disease; therefore beaks are not pigmented; note that lack of keratinization may also be due to low temperature (RACHOWICZ 2002) and thus not an abnormal condition

Bent tail | The tail is bent instead of being straight; → kinky tail is a synonym

Bicephaly | Head duplication; a synonym of → dicephaly and → catadydimus

Brachycephaly | Head abnormally short but of normal width; in post-embryonic stages, this type of anomaly is rare (VERSHININ 2015, HENLE et al. 2017a)

Brachygnyathia | Abnormal shortness of the lower jaw (METEYER 2000, LANNOO 2009); usually either used

as a subcategory or a synonym of → mandibular hypoplasia

Brachyuria | Shortened tail (ROTHSCHILD et al. 2012); note that the term is used only for inherited shortness of tails and not for lost parts of a tail; this term is rarely used in the literature on amphibian anomalies

Catadydimus | Two headed (WALLACH 2007); a synonym of → dicephaly and → bicephaly that is frequently used for snakes but rarely for amphibians

Cataract | Clouding of the eye lens, which leads to a decrease in vision

Cauda bifida | Terminal part of tail duplicated (Fig. 44)

Cleft lip | Lip with a fissure (Fig. 45)

Curvature of tail | → Bent tail

Cyclopia | Eyes completely fused into one single median eye (ADELMANN 1936). Note that some Russian authors (e.g. FAYZULIN 2011) call unilateral → anophthalmia cyclopia

Dicephaly | Two heads (Fig. 46; OUELLET 2000); → bicephaly and → catadydimus are synonyms



Fig. 43: Anophthalmia in a captive bred *Cruziophyla cf. calcifer*, 18.1.2009. Photo: J. KAESLING.



Fig. 44: Cauda bifida in a tadpole of *Hyla arborea*; Thriptis Mountains, Crete, Greece, 30.8.1999. Source: HENLE et al. (2012); Photo: K. HENLE.

Duplicitas anterior | Duplication of anterior parts of the body; → Janus twins is a specific form of it; SCHMIDT (1930) restricted the term to duplication of the head, i.e. used it as a synonym of → dicephaly; KABISCH (1990) included → polymely of the forelimbs (i.e. → melomely) under this term

Duplicitas posterior | Duplication of posterior parts of the body; KABISCH (1990) included → polymely of the hindlimbs (i.e. → pygomely) under this category

Exophthalmia | Eyes protruding abnormally

Eye displacement | Eye displaced laterally, medially, cranially or caudally (LANNOO 2008, 2009, NEKRASOVA 2008); called abnormal eye position by VERSHININ (2015)

Gigantism | Body size much larger than the normal maximum size

Gut miscoiling | Abnormal coiling of the gut; most common is a loose coiling

Hump | → Kyphosis of the spine

Hypognathia | A synonym of → mandibular hypoplasia and → mandibular dysplasia



Fig. 45: Cleft lip, presumably due to injury, in an adult *Bufo bankorensis*; Taroko, Taiwan, 2.12.2012. Photo: K. HENLE.



Fig. 46: Dicephaly in a captive born larval *Salamandra salamandra* (GROLICH & GROSSE 2013). Photo: C. GROLICH.

Janus twins | Duplication of dorso-anterior structures in the absence of duplication of posterior structures; i.e. a specific form of → duplicitas anterior

Jaw shape abnormal | Jaw fully developed but upper and lower jaw differ in shape and mouth does not close completely

Jaw sheaths abnormal | A specific form of abnormal → mouthparts in larval amphibians, in which there are unnatural breaks, gaps or other deformities in the jaw sheaths or the jaw sheaths may lack keratinization

Keratinized denticles absent | The labial tooth rows lack denticles or denticles are not keratinized in species that normally have keratinized denticles; a specific form of → tooth rows abnormal

Kinking | Torsion of notochord, vertebral column or tail; → kyphosis, → lordosis and → scoliosis are specific expressions of kinking

Kinky tail | → Bent tails (TYLER et al. 1989); a specific form of → kinking, in which the tail is affected

Kyphosis | Abnormal backward curvature of the spine (tail or body) (METEYER 2000, OUELLET 2000, JOHNSON et al. 2010); a specific expression of → kinking; note that METEYER (2000) does not include → lordosis in her glossary, while USFWS (2007) included it but not kyphosis; they seem to use the two terms as synonyms, as is also indicated by photos on the website <http://www.fws.gov/contaminants/amphibian/PictureThumbs.html>

Labial papillae abnormal | Labial papillae underdeveloped, interrupted or absent

Laceration | Skin wound (Fig. 47)

Lesion | Pathological area of an organ (ROTHSCHILD et al. 2012); may be due to injury, disease or → tumour

Lordosis | Abnormal forward curvature of the spine (tail or body) (OUELLET 2000, JOHNSON et al. 2010, ROTHSCILD et al. 2012, VERSHININ 2015); a specific expression of → kinking; note that USFWS (2007) does not include → kyphosis in its glossary, while METEYER (2000) included it but not lordosis; they seem to use the two terms as synonyms, as is also indicated by photos on the website <http://www.fws.gov/contaminants/amphibian/PictureThumbs.html>

Macropthalmia | Abnormally large eyes (FODOR & PUKY 2002)

Mandibular dysplasia | A synonym of → mandibular hypoplasia (JOHNSON et al. 2001, SESSIONS 2003), the latter being more commonly used

Mandibular hypoplasia | Lower jaw underdeveloped or completely missing (TYLER 1989, JOHNSON et al. 2010) but the term may be used also in a more restrictive way that excludes completely missing jaws. → Brachyglossia and → agnathia are specific types of mandibular hypoplasia as defined here. The following terms are less commonly used synonyms: → mandibular dysplasia, → hypognathia and → micrognathia

Maxillary hypoplasia | Upper jaw underdeveloped or completely missing

Microcephaly | Abnormally small head (METEYER 2000, USFWS 2007, NEKRASOVA 2008, ROTHSCILD et al. 2012); either the whole head or parts thereof may be reduced in size or shortened. LANNOO (2008, 2009) defined the term differently: “blunt nose; shortened upper jaw”; while such an anomaly is a specific form of microcephaly, most authors define the term more broadly; for a shortened upper jaw a different technical term exists: → maxillary hypoplasia; moreover, etymologically, “micro” means “small” and “cephaly” means “head”. Microcephaly is a rare type of anomaly with the exception of embryos

Micrognathia | A synonym of → mandibular hypoplasia (NEKRASOVA 2008)

Microphthalmia | Eye(s) abnormally small (Fig. 48) (METEYER 2000, OUELLET 2000, NEKRASOVA 2008, LANNOO 2009, JOHNSON et al. 2010, VERSHININ 2015); sometimes also spelled microophthalmia; as a lapsus



Fig. 47: Laceration (skin wound) on the head of a juvenile *Rana arvalis*; in early stages of healing, the skin is transparent; Samarowo, Russia, 17.8.2012. Photo: K. HENLE.

calami, LANNOO (2008) called this type of anomaly anophthalmia

Monorhyny | Having a single nostril (ROSTAND 1958, OUELLET 2000, ROTHSCILD et al. 2012, VERSHININ 2015); so far only cases are known that are caused by a fusion of the nostrils, i.e. → synrhyn

Mouthparts abnormal in larvae | Beaks, labial teeth rows or labial papillae reduced in size, number or form, misplaced or abnormal in shape

Mydriasis | Excessive dilation of the eye (STREICHER et al. 2010)

Myiasis | Lesions caused by the maggots of parasitic flies that deposit eggs on living individuals; in severe cases, the nasal openings may be destroyed (Fig. 49)

Nanism | Body size much smaller than normal; in natural populations this type of anomaly is very difficult to distinguish from small individuals that are still in the process of growing

Nares closed | Failure of nostrils to open

Nasal opening destroyed | This anomaly is caused by maggots of the parasitic fly *Lucilia bufonivora* that deposits eggs on the nostrils or other body parts (Fig. 49); the larvae migrate to the nostrils and destroy them killing the infected individual; usually *Bufo bufo* is the host but rarely other species are also parasitized (HENLE et al. 2017a)

Nose blunt | Nose truncated in species that usually have a rounded snout

Opening underneath opercular fold unusually wide | Resorption of the opercular fold was abnormally large

Ophistocony | Used as a synonym of → lordosis by FLINDT & HEMMER (1967)

Oral labial papillae swollen | A specific form of the category → mouthparts abnormal, in which the labial papillae are expanded in size

Osteolathyrism | Decreased connective tissue strength (SNAWDER & CHAMBERS 1993); this anomaly leads to notochord and tail deformities in embryos and to → joint dislocation and → bent long bones in metamorphosing anurans

Otocephaly | Absent or underdeveloped lower jaw (ROTHSCILD et al. 2012); this definition includes → mandibular hypoplasia and → agnathia; both terms were not included in the glossary of ROTHSCILD et al. (2012); whereas we did not find any use of the term otocephaly in the literature on amphibian anomalies, the latter terms are commonly used

Palatine eye | Eye in the mouth (OUELLET 2000)

Panophthalmitis | Infection of the whole eye

Polyophthalmia | More than two eyes (FODOR & PUKY 2002)

Sacrum asymmetric | Sacral processes inserted on different vertebrae

Scars | Skin wound, scratches; may not be abnormal in territorial species that fight with each other

Scoliosis | Abnormal lateral curvature of the spine (tail or body) (METEYER 2000, OUELLET 2000, LANNOO 2008, JOHNSON et al. 2010, ROTHSCILD et al. 2012, VERSHININ 2015); a subcategory of → kinking

Siamese twins | Two almost complete individuals that are fused to each other and share most body parts

Skeletal kinking | → kinking involving the skeleton

Snout pointed | Snout is pointed instead of being round in species that normally have a round snout

Spiraculum number abnormal | More or fewer than the normal number of spiracula (HÉRON-ROYER 1884); most tadpoles have a single spiraculum as the normal phenotype but tadpoles of rhynophrynid, pipids and *Lepidobatrachus* have two spiracula (McDIARMID & ALTIG 1999)

Spiraculum misplaced | Spiraculum on the wrong side of the body or ventrally in species in which the normal position is lateral; the most common normal phenotype is a single spiraculum on the left side of the body (McDIARMID & ALTIG 1999)

Synrhyn | Fused nostrils; so far this type of anomaly is the only known form of → monorhyn

Tail bifurcation | → Cauda bifida

Tail duplication | Tail is partially or completely duplicated; includes → Asyntaxia caudalis and → Cauda bifida as subcategories

Tail fin reduced | Parts of the tail fin lacking or reduced in height

Tail retention in metamorphosed anurans | Tail is not completely reabsorbed during metamorphosis; note that in some species tail resorption may be completed only after individuals have left the water (VERSHININ 2015, HENLE et al. 2017a)

Tail stunted | Tail shorter than normal (TYLER 1989)

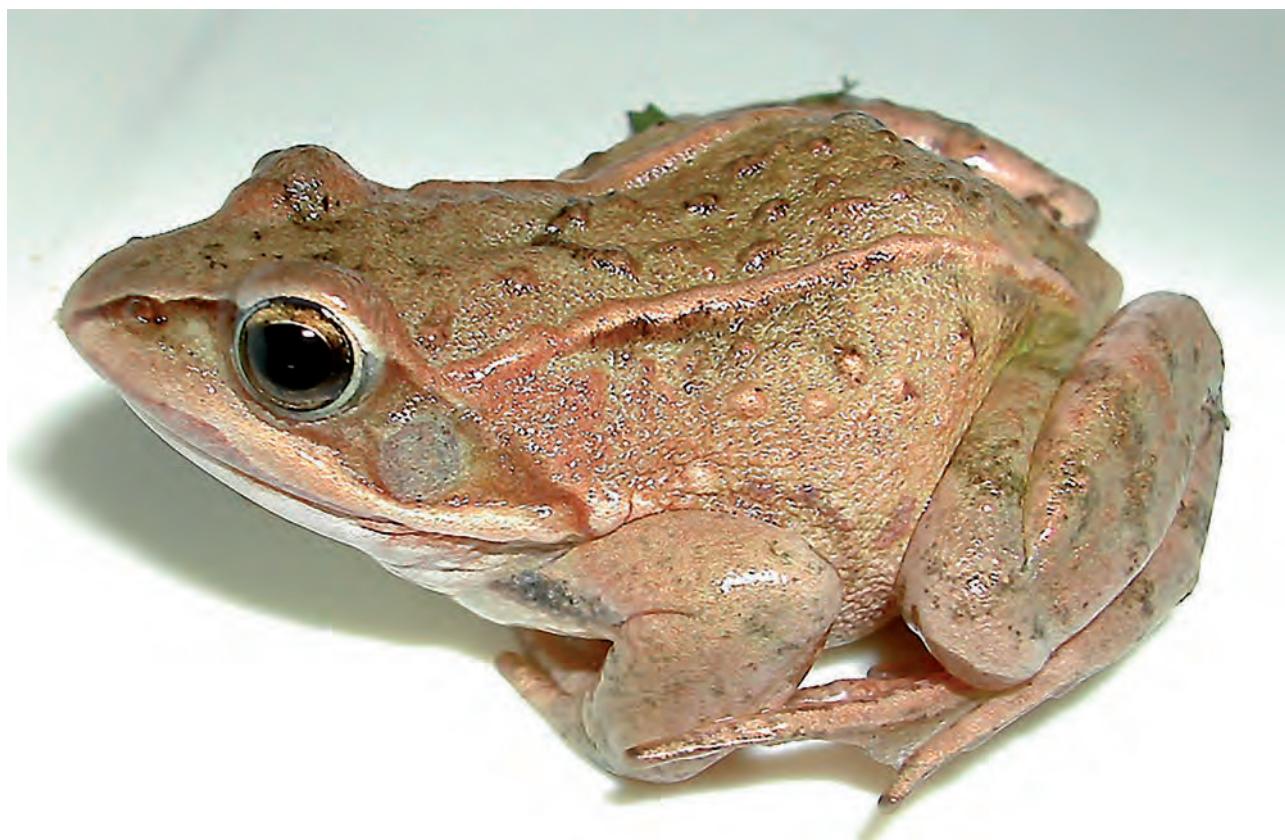
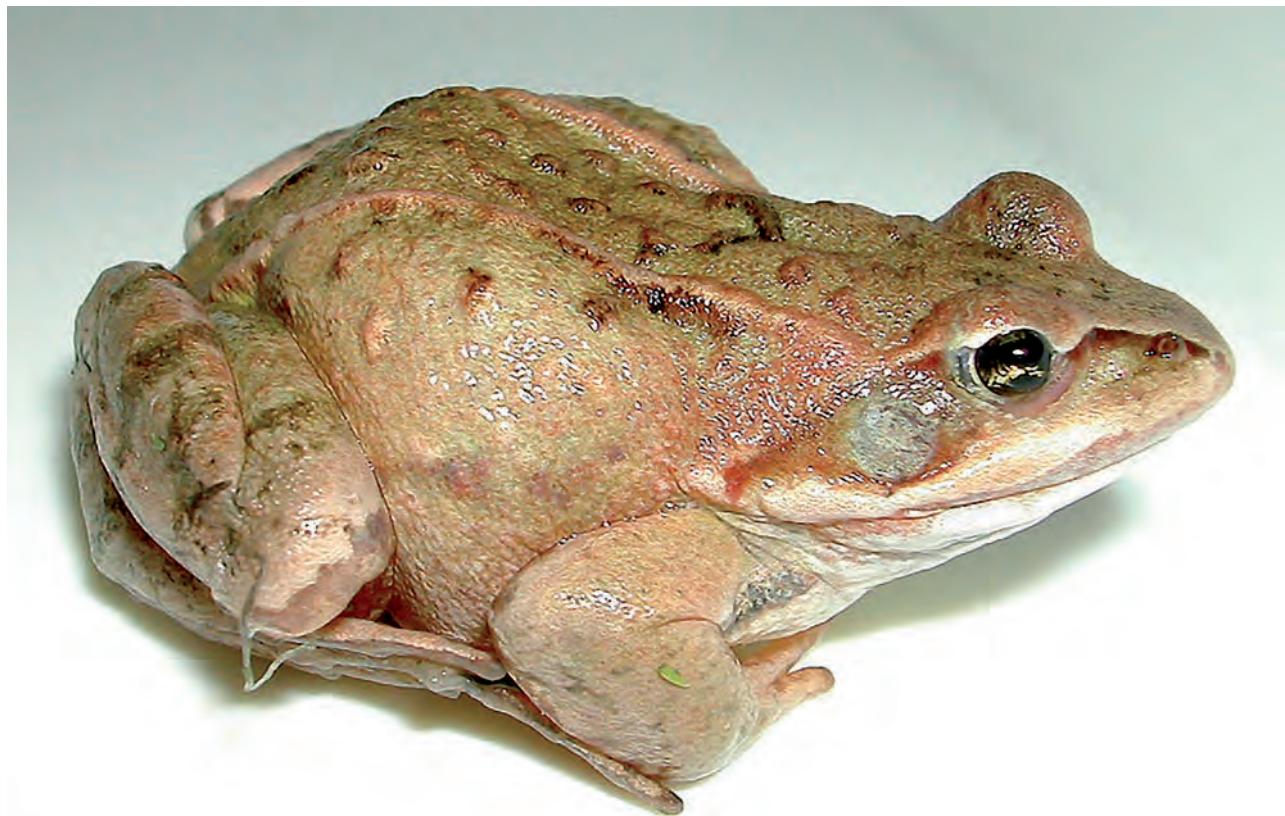


Fig. 48: Microphthalmia (top) in an adult male *Rana arvalis*; for comparison the normal eye of the left side is shown (bottom); Ekaterinburg, Russia, 5.9.2003. Photo: V. VERSHININ.

Tooth rows abnormal | Tooth rows in tadpoles mis-shaped, interrupted, lacking denticles or → keratinization of denticles absent

Torsion of body | → kinking

Torsion of tail | → Bent tails

Twinning | Duplication of body parts; → catahydromus, → dicephaly, → duplicitas anterior, → duplicitas posterior, → Janus twins, → Siamese twins are specific forms of twinning; duplications that involve only the limbs, the tail or parts thereof are usually not called twinning

Tympanum absent | Abnormal in species whose normal phenotype is an externally visible tympanum; note that in some species this is the normal condition

Urostyle bent | Curved bones of the urostyle (VERSHININ 2015)

Vertebral column stiff | Vertebral column immovable, usually due to → vertebral fusion

Vertebral fusion | Two or several vertebrae are fused

Vertebral column truncated | Vertebral column considerably reduced in length (HENLE et al. 2017b: Fig. 9)

2.3 Edema, tumour and similar types of anomalies

GREEN & HARSHBARGER (2001) provided a terminology for anomalies related to tumours and BANTLE et al. (1991) and GREEN (2001) explained terms related to edema. Here we only include terms for externally visible anomalies. Many of these types of edema occur frequently in embryos but are rarely observed in the field at later stages of development.

Ascites | → Edema of the peritoneal cavity (belly) (Fig. 50; OUELLET 2000); → hydrocoelom is a synonym; since amphibians do not have separate thoracic and abdominal cavities, the term is regarded as inappropriate for amphibians by GREEN (2001); some authors (e.g. FERNANDEZ & BEETSCHEN 1975) used the term more broadly as a synonym of edema

Blister | A vesicle of the skin containing fluid (BANTLE et al. 1991); a specific type of → edema

Bloatedness | Swelling of the entire body; usually no differentiation is made as to whether gas or liquid accumulation caused bloatedness (e.g. LANNOO 2009), and it is not always easy to make this distinction in the field; we recommend using either → gas accumulation or → edema when the cause (gas / liquid) of the swelling is known



Fig. 49: Nasal openings destroyed by maggots of *Lucilia bufonivora* in an adult *Bufo bufo*; Bialogard, Poland. Source: Wikipedia Commons. Photo: R. ALLENKAMP



Fig. 50: Edema in a juvenile *Lissotriton vulgaris*; Ekaterinburg, Russia, 16.9.1980. Photo: V. VERSHININ.

Carcinoma | Malignant form of → neoplasia; contains → melanoma as a subcategory

Cephalic edema | → Edema of the head; → hydrocephaly and → hydroencephaly are generally used as synonyms, though the latter does not necessarily involve the whole head in tadpoles or later stages

Cyst | Swelling caused by abnormal tissue growth to encapsulate parasites; also used for swellings that contain mushy material; the definition for cysts makes it a subcategory of → tumour but usually the term cyst is regarded as a separate category

Dysplasia | Abnormal development of structures, such as muscles or organs, conventionally used for non-malignant abnormal structures (ROTHSCHILD et al. 2012)

Edema | Subcutaneous accumulation of fluid (Fig. 50; JOHNSON et al. 2001, 2010, SESSIONS 2003, VERSHININ 2015); → hygroma is a rarely used synonym; → hydrops is used as another synonym by some authors but regarded as a subcategory by others; edema is a subcategory of → bloatedness and contains the following subcategories: → ascites, → hydrocephaly, → hydrocoelom and → hydroencephaly

Epithelioma | A synonym of → papilloma (PFEIFFER et al. 1979)

Gas accumulation | A subcategory of → bloatedness, in which the swelling of the body is caused by gas

Granuloma | → Tumour caused by an inflammatory swelling (GREEN & HARSHBARGER 2001)

Gut miscoiling | Abnormal coiling of the gut; most common is a loose coiling

Hydrocephaly | → Edema of the head (e.g. HERTWIG 1911); → cephalic edema is a synonym; because the most common form is an enlargement of the brain ventricles due to an excessive amount of fluid; hydrocephaly and → hydroencephaly are generally used interchangeably (e.g. PACCES-ZAFFARONI et al. 1978)

Hydrocoelom | Fluid accumulation in the body cavity (Fig. 50); a synonym of → ascites, if ascites is defined as it is here

Hydroencephaly | → Edema of the brain (BANTLE et al. 1991, VERSHININ 2015); → hydrocephaly is often used as a synonym, although strictly speaking hydroencephaly is a specific form of hydrocephaly in which the brain is affected

Hydrops | A synonym of → edema; GREEN (2001) preferred to use this term only for cases in which the subcutis, tissues and coelomic cavity of larval amphibians are jointly affected; ELKAN (1976) used it for edema of the subcutaneous lymph sacs in larval and adult amphibians

Hygroma | Used as a synonym of → edema by LANNOO (2008)

Hyperplasia | Abnormally strong development of structures, such as muscles or organs; a subcategory of → tumour

Melanoma | Malignant → neoplasia arising from the melanocytic system of the skin (ROTHSCHILD et al. 2012) or other organs; melanomas are characterised by black pigmentation

Neoplasia | Development of abnormal new structures (GREEN & HARSHBARGER 2001, ROTHSCILD et al. 2012, VERSHININ 2015); a subcategory of → tumours; contains → carcinoma as a subcategory

Nodule | → Swelling or lump; may be filled with lipids, viral particles, spores of fungi or parasitic microorganisms; often an initial stage in the formation of tumours (e.g. LUCKÉ & SCHLUMBERGER 1949)

Papilloma | → Neoplasia in which the ectoderm shows an abnormal outgrowth in the form of a horny epithelium or warts (Fig. 51); plural: papillomas or papillomata; → epithelioma is a synonym

Ulceration | Sore or lump; may originate from infection or tumour (e.g. LUCKÉ & SCHLUMBERGER 1949)

Tumour | Abnormal mass of tissue resulting from excessive cell division (Fig. 51); a tumour may be inflammatory (→ granulomata), parasitic (encysted immature trematodes), → hyperplastic or → neoplastic (GREEN & HARSHBARGER 2001); malignant tumours are called → carcinoma; note that abnormal tissue mass produced to encapsulate parasites is most commonly referred to as a cyst and not as a tumour, though the definition of tumours also includes cysts

2.4 Anomalies of eggs and early embryonic stages

As most of these anomalies are only studied in the laboratory, here we only list a few types of anomalies that can easily be detected in the field with a hand lens. See BANTLE et al. (1991) for a more detailed description of various embryonic anomalies

Acephaly | Head structures lacking

Asyntaxia medullaris | A synonym of → spina bifida

Axial duplication | → Spina bifida

Clutch abnormal | Common clutch anomalies are clutches lacking eggs (Fig. 52), eggs without embryos, twin embryos, membrane lacking between embryos (Fig. 52) and abnormally white eggs (see → albinism and → transient albinism in section 2.1) (VERSHININ 1991, 2002)

Cyclopia | Eyes completely fused into one single median eye (ADELMANN 1936, SIGNORET 1960); ZAKS (2008) and FAYZULIN (2011) used the term as a synonym of unilateral → anophthalmia

Microcephaly | Head reduced in size (NEKRASOVA 2008)

Spina bifida | Duplication of (parts of) the vertebral column, usually combined with duplications of major parts of the body (HERTWIG 1892); ontogenetically, the



Fig. 51: Papilloma in *Cynops pyrrhogaster*; Japan. Photo: M. ASASHIMA & V.B. MEYER-ROCHOW.

correct name should be → asyntaxia medullaris (BARFURTH 1900) but this name has not become established (see also → twinning; → Siamese twins)

Supernumerary appendages | Duplication of embryonic structures

Synophthalmia | Eyes are close-set, can adhere more or less to each other but remain distinct, which distinguishes it from → cyclopia (SIGNORET 1960)

2.5 Other terms

Abnormality | Gross deviation from the normal range in morphological variation (JOHNSON et al. 2001, USFWS 2007)

Aneuchrony | The speed of development is accelerated or delayed compared to the normal condition (DUBOIS

1987); → heterochronic and → homochronic aneuchrony are subcategories

Anomaly | Any deviation of the phenotype (morphological and non-morphological) from the range of variation of the phenotype considered to be normal and irrespective of its cause

Deformity | Alteration of an organ or structure that originally formed correctly (JOHNSON et al. 2001, USFWS 2007)

Heterochronic aneuchrony | Dissociation of the development rate of characters, some being either accelerated or decelerated compared to the normal development rate of other characters (DUBOIS 1987); → neoteny is a common form of heterochronic aneuchrony

Homochronic aneuchrony | The speed of development deviates from the normal rate for all characters (DUBOIS 1987)



Fig. 52: Abnormal clutches of *Salamandrella keyserlingii*: left: eggs arranged in strings lacking individual membranes; right: abnormally low number of eggs; Ekaterinburg, Russia, 7.5.2002. Photo: V. VERSHININ.

Malformation | A permanent structural defect resulting from abnormal development (JOHNSON et al. 2001, USFWS 2007)

Neoteny | A specific form of → heterochronic aneuphrony, in which development of the somatic characters is delayed or arrested but not that of gonads, so that the resulting giant larvae are able to reproduce (Fig. 53) (DUBOIS 1979)

Paedomorphosis | Retention of juvenile traits in adults (DUBOIS 1979)

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Fig. 53: Neoteny in a *Lissotriton vulgaris meridionalis*; Croatia 25.6.2010. Photo: B. TRAPP.

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