Mem. Inst. Butantan
Simp. Internac.
33(1):55-59, 1966

6. BIOLOGICAL SIGNIFICANCE OF CUTANEOUS SECRETIONS IN TOADS AND FROGS

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The skin plays a very important role in the biology of the **AMPHIBIA ANURA**, i.e., Toads and Frogs. It subserves the respiratory function, since pulmonary respiration is not quite adequate for their needs. It is a naked skin unprovided with scales. It is kept moist thus permitting gaseous exchanges through the superficial capillaries.

The skin of the **ANURA** receives a special blood-supply over a large area of the body through cutaneous arteries and returns it through musculocutaneous veins. The total respiratory capillary length of the skin varies from 20.5 to 65.1 in the anurans studied for this factor. It is greater in thin-skinned and in aquatic forms than in terrestrial toads with a glandular skin and better developed lungs. Classic and modern studies of certain species show that carbon dioxide is mostly excreted by the skin and varies with physiological condition and activity where as the intake of oxygen by the lungs, being dependent on outside tension, is more constant.

Two main types of multicellular glands occur in the skin of adult Anurans: mucous glands and granular glands. The mucous glands produce a rather fluid secretion which lubricates the skin. The granular glands produce a creamy granular secretion which contains poisonous substances. The skin glands may be disseminated over the body but they tend to become localized and form masses at certain points, especially the granular glands. Some frogs, such as the neotropical genus *Cyclorhamphus* and a number of small kinds of *Paludicola*, have gelatinous glandular disks on the flanks. In the genus *Bufo*, which comprises the true toads, the granular glands form large masses in the postocular region; they are called paratoids, from a false analogy with the parotoid glands of mammals. Some other frogs also have parotoids, f.i. the large species of neotropical tree-frogs belonging to the genera *Phyllomedusa* and *Pithecopus*, but their parotoids are long and thin and continue along the dorsolateral edges of the body. The skin glands of Anurans, especially the glandular glands of toads, are of interest to students of Venomous Animals on account of the poisonous substances contained in their secretions but they are well-known in only a few genera and species.

From a biological point of view the skin glands of the **ANURA** are a mechanism of defense which aids survival of the individual.

The slimy secretion of the mucous glands is greatly increased the moment a frog is seized and makes it difficult to maintain the hold, the more so as lubrication is accompanied by intense wriggling to get away. The secretion frequently

has a strong odor, for instance of pepper, garlic, crushed leaves, or musk. It is often sternutatory and sometimes induces tears. Some frogs, like the garlic toad, or "Knoblauchkroete", *Pelobates*, cause the death of other frogs put into the same container with them. Another European frog, *Bombina*, can be kept alive in a vivarium full of turtles because it is not attacked by them. One of the most interesting cutaneous secretions is that of the large, glandular species of tree-frog of the neotropical *Hyla venulosa* group. The secretion dries to a rubbery consistence. Often, but not invariably, it provokes a reaction after handling the frogs.

These substances are poorly known. Their virulence may vary from one form to another but possibly also in the same form at different seasons or in different physiological conditions. My former assistant Miss Kloss had a prolonged and violent headache on inadvertently rubbing her eyes soon after handling the Amazonian form of *Hyla venulosa*. Other specimens, from Belém do Pará, very much handled by me, caused no symptoms at all. A painful rash, lasting a few hours came out on my hand and arm after catching a *Hyla imitatrix*, of the same group, dropped by a bird scuffling with it. The other frogs put with it arrived dead and glued together. Another specimen of the same form left a painless weal, which lasted many days, on my hand by laying a leg across it. The bromealiad collectors Mr. and Mrs. Racine and Mulford Foster called the Chaco form, *Hyla hebes* Cope, the "india rubber frog", because the secretion was abundant enough to permit them to make small pellets with it. Neither they not I felt any effects from it, even when I rubbed it on the inside of my lip. Professor Mertens mentions a burning sensation on seizing the unrelated *Hyla vasta* from Santo Domingo.

The secretions of the parotoid glands of the true toads are easier to obtain and have been studied more consistently. A number of poisonous substances have been extracted from them and named. There seem to be specific differences. However, these glands also constitute a mechanism of defense. Their secretion is seldom released spontaneously and even then after a great deal of provocation has been endured. The author only saw it spurt out once, in a toad that hit the ground after being dropped from a height. Nor can the toads introduce their venom into the body of their enemies. For it to take effect, the glands have generally got to be bitten into. Small dogs have worried toads may die or become very ill as a result of their indiscretion but the toad is a passive element. Experiments with toad venom by injection may be of biochemical interest but biologically they are artificial and disregard natural conditions.

Cutaneous secretions are supplemented by a few other simple defense mechanisms. The first is derived from the integument and is the coloring, especially of the permanently visible dorsal aspect. There are two main types of protective coloration, procrypt and aposematic. In procrypt animals the color is concealing either by resemblance to the background, or by a disruptive pattern which conveys a false outline and breaks up the visual image of the surface. The tree-frogs *Phyllomedusa* and *Pithecopus* are protected by similarity to the background. They live on the vegetation and in day-time the dorsal aspect is uniformely green. The color is brusquely out off at the edges of the permanently visible surfaces and thus separates them abruptly from those concealed in repose, which may have bright spots of aposematic color on them. At night, when they move about, the large species become very dark, purple or chocolate-colored, almost black. The true toads, *Bufo*, may have a uniform or mottled dorsal

surface, with a sexual dichroism in some species; which is very unusual in Anurans. The color may blend into the background or the surface be disrupted by mottling. *Bufo typhonius* and other forest-forms may look like leaves from above; some of them, like *Bufo guttatus*, are so dark beneath that they seem flat. In aposematic frogs, the bright coloring is seldom general, though it is uniform in a few, f.i., the minute pumpkin-colored *Brachycephalus ephippium*. As a rule, the bright colors either serve to disrupt the visible surface or they are flash-colors, often on the thighs, which are only seen momentarily when the frog moves.

An additional means of defense derives from increase of ossification, in direct opposition to the evolutionary reduction of the skeleton from ancient to recent amphibians. Some have a bony shield on the back, such as the tiny *Brachycephalus ephippium* just mentioned and the huge horned toads. More often the increased ossification is on the top of the head, the part of the body most vulnerable to attack. Many species of *Bufo* have bony crests which stand out; they vary from species to species and are used in taxonomy. Their greatest development is attained in *Bufo typhonius*, old and large specimens of which may have veritable wings to the sides of the head. Other toads develop a more or less complete skull-cap or helmet; these are burrowing forms. The function of these adaptative structures evidently is to prevent seizure and crushing of the head.

Habits and patterns of behaviour also provide means of defense. Nocturnal life is the rule in frogs and toads. One way of avoiding their enemies is by hiding and sleeping in day-time in holes and burrows, both natural or artificial (ground-dwellers), in bromeliads or among leaves (tree-frogs). Only the most agile running-water frogs, f.i., *Elosia* and *Megalosia*, can afford the luxury of diurnal life.

Some anurans have evolved attitudes of defense. The best known is probably the "Unkenreflex", from the German popular name "Unke" for the genus *Bombina*. It consists in arching the body with the back uppermost and curving the limbs up over it and the head, bringing the flash-colors of the ventral aspect into evidence. Many neotropical tree-frogs "play possum", lying quietly on the ground as if dead, while they await the chance to turn rapidly and leap away. Toads inflate their lungs to the utmost. Some rear up on their hind legs and butt with their heads. Others lean to one side and present a lateral view to the predator. This greatly increases the surface that has to be bitten into or swallowed. *Holaden bradei*, a minute toad from the Itatiaia, which lays terrestrial eggs and guards its nest, also rises on its legs and leans forward, hissing, when its spawn is threatened.

The simple mechanisms enumerated above exhaust the modest arsenal of defense of the toads and frogs, leaving them often at the mercy of their enemies. Some are better protected than others, f.i. the Antillean, phragmotic, casque-headed, toads which live in the ground and plug the openning of the burrow with their heads. Small toads with insignificant crests, like *B. granulosus*, hiding in hollows in dunes are however sometimes yanked out of their mobile homes by the head by snakes, as observed by Gliesch in Rio Grande do Sul. The British naturalist Loveridge once saw a rat rip the skin off a toad down the middle of the back and start to devour its flesh. He also observed other small mammals avoid the parotoids by tumbling over the toad and attacking it from the belly. In nature the predator-pray relationship is apt to be less favorable to anurans than to their enemies and loss may have to be compensated for by excessive spawning or by protection of eggs and larvae; this is done in many ways, beginning with the unpalatable and perhaps poisonous eggs of toads. They are seldom interfered with.

Among their enemies the **AMPHIBIA** must reckon human beings.

Toads have been barbarously used in witchcraft and primitive medicine; to this day many are flayed alive for their skins and let loose to die or be devoured by fire ants. The Tucana Indians imprison the large *Phyllomedusa bicolor* in little cages like birds. After bouts of drinking and gorging they scarify the skin at the temples and wrists and rub the paratoids of the frog on the scratches to bring on vomiting and catharsis. Many beautiful little frogs of the genus *Dendrobates* are caught by Amazonian Indians and impaled alive on sticks to roast over the fire; the agonic gouts of poison gained are used on arrows for killing monkeys and other small game. Can one really consider Venomous Animals those that never attack and can barely defend themselves? In the interests of science one must study them but the study should be carried out in a logic and in a humane manner.

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Discussion

H. Edery: "During the last years Prof. Erspamer and his collaborators have found in the skin of a number of frogs and toads extremely active peptides, some them related to bradykinin. Have you any information how they are formed? Are they originated in precursors proteins? The second question: which are the natural enemies of these frogs and toads you mentioned? I suppose they should be particular sensitive to the venom. Have you any information on this point?"

B. Lutz: "First question: I am afraid that I do not know the answer, but I refer you to Dr. J. M. Cei of the University at Mendoza, Argentina, who will answer your question.

Second question: The main enemies are snakes, arboreal (tree-frogs), terrestrial and aquatic. They seize the frogs by the head. Those which are casgne-headed are better protected, especially if they are phragmotic, taking refuge in a cavity and plugging the lienem with a snake. I once observed a *Bothrops jararaca* trying to get one out of a bromealiad, unsuccessfully. Those with less perfect helmet, like small *Bufo granulus* with crests only, are less well protected. They live in holes in the dunes, are janked out of their mobile burrow by the head, as seen by Prof. Rudolph Gliesch in Rio Grande do Sul.

Tree frogs, both male and female, seized by snakes, give a loud cry of distress. Mammals also sometimes eat frogs and toads. I presume that some of the predators are insensitive to the venom or avoid biting directly into the parotid glands. Dr. Freiberg of Argentina saw a very large chulean frog, *Calyptocephalella goeji*, swallow toads.

A British naturalist, Loveridge, saw a rat attack a toad in the middle of the back, behind the glands. He also saw small mammals tumble over the toad and attack it on the belly. I mentioned a birth that released, in mid-air, a *Hyla imitatrix* with irritant secretion. Aquatic frogs may be attacked by leeches. Many neotropical ones, especially bromeliad-dwellers, have larval mites in the skin. Some mosquitoes bite frogs. They also have worms, f.i. *Trematodes*. Dr. Adolpho Lutz found an oligochaete worm *Schomardaella lutzi* Michaelson in the bladder of some tree-frogs."