
Andrzej Jasiński† and Adam Miodoński

Departments of Comparative Anatomy and Neuroanatomy, Institute of Zoology, Jagiellonian University, Kraków, Poland

Received September 12, 1980

Summary. Corrosion casts of the blood vessels in the oral mucosa of *Rana esculenta* were examined by the scanning electron microscope. Special attention was paid to the palatine capillaries characterized by numerous blind diverticula. Microanatomy and topography of these peculiar vessels suggests their involvement in gas exchange. The diverticula of the capillaries visible in the casts in form of nodules of various shape and size were examined in detail.

In the majority of amphibians the oral mucosa is furnished with a peculiar type of capillaries which form numerous blind diverticula, described for the first time by Bethge (1898). The present report is a continuation of our morphological analysis of the vascular bed of the respiratory organs in amphibians (Jasiński and Miodoński, 1978; Miodoński and Jasiński, 1979) and deals with the topography of the blood vessels of the oral mucosa in frogs of the *Rana esculenta* L.

MATERIALS AND METHODS

Large individuals of *Rana esculenta* L. were used. The animals were anesthetized with 0.5% tricaine (MS 222) injected intraperitoneally or into the craniodorsal sac. The blood was washed out via truncus arteriosus and the right auricle by injection of heparinized phosphate-buffered salt solution. Afterwards, following the injection of 0.5% glutaraldehyde, the circulatory system was filled with "Mercox" resin. The clean casts of the vascular network of the oral mucosa were frozen in distilled water, freeze-dried, mounted on stubs with a conductive glue, and then coated with gold in a vacuum evaporator. Observation was carried out using a JSM-35 scanning electron microscope at 10-25 kV.

A more detailed account of the procedure employed has been published earlier (Jasiński and Miodoński, 1978).

* This work was supported by grant number 222/II from Zoological Committee of the Polish Academy of Sciences.
† The Editor wishes to express his regret over Professor Jasiński's death (October, 1980) while this paper was in press.
Fig. 1. Scanning electron micrographs of the corrosion casts of the subepithelial capillary network of caudo-lateral (A) and caudo-medial (B) areas of the palate in *Rana esculenta.* × 65
RESULTS

The respiratory vessels of the oral cavity in *Rana esculenta* occur as a capillary network of irregular density and of various size and shape meshes. Most typical and characteristic are palatine capillaries. The tongue of *Rana esculenta* and other anurans possesses a vascularization fundamentally different from that represented by the respiratory vessels in the mucosa of the oral cavity.

The mucosa of the caudal part of the palate forms numerous longitudinally oriented folds. The capillary network of this region is folded, although in the remaining parts of the palate it is flat and uniformly distributed (Fig. 1). The most striking feature of the palatine capillaries is the presence of blind diverticula, which are visible in the casts as small projections or nodules. The diameter of the capillary lumen as well as the number of the diverticula show great regional differences (Fig. 2). The capillaries with the smallest diameters cover the edges of the palate, while the largest ones occur in the vicinity of the choanae.

The details of the morphology of frog palatine vessels, as seen in the casts, are

---

**Fig. 2.** Scanning electron micrographs of the corrosion casts of the capillary network in the antero-lateral area (A) and the antero-medial area (B) near the choanae, in the palate of *Rana esculenta*. In both photographs compare the diameters of the capillary casts and number and dimension of the nodules, which correspond to the blind diverticula of the capillaries. ×120
Fig. 3. Some details of the capillary network in the frog oral mucosa. A. Group of capillaries confluent to a single vein (V). B. Higher magnification of the network indicating arrangement of vessels in the medial region of A. Arrows indicate the presumed direction of blood flow. Note the differences in distribution, size and shape of the particular nodules. A: ×160, B: ×380
Vascular Arrangement in Frog Oral Mucosa

shown on Figure 3. The diverticula occur exclusively on that side of the vessels which faces the oral cavity. The opposite side lacks such outgrowths. However, the distribution of these diverticula varies in particular vessels. Three typical patterns of arrangement can be distinguished: a single row, an alternating pattern and a double row.

Most frequently the diverticula are distributed in line; the consecutive diverticula may be shifted alternately to either side of the vessel; finally they may occur in pairs. The diameter of the diverticula is greatly variable and ranges from 6 to 40 μm. The height of the diverticula also varies, but usually does not exceed their diameter. Large diverticula may often be divided secondarily into various numbers of shallow compartments.

DISCUSSION

Arterial blood reaches the palatine vessels via arteria carotis interna whose distal segment forms the a. palatina. The vessels in the floor of the oral cavity and in the tongue are supplied with a. carotis externa, the continuation of which is a. lingualis. The external and internal jugular veins receive the venous drainage from the oral mucosa.

Considering the distribution of the afferent and efferent vessels, the morphologically uniform and flat capillary network of the oral mucosa can be divided into numerous small areas in which the blood flows centripetally (Fig. 3). The periphery of these areas is supplied by the smallest afferent vessels (arterioles), while the drainage from the area occurs through the centrally located collecting venules. A vascular architecture of such a type, which we have called a “mosaic,” has been previously described in the skin of Rana esculenta (Jasiński and Miodoński, 1978), and Salamandra salamandra (Miodoński and Jasiński, 1979).

The density of the capillary network in the palate, expressed by the number of meshes per 1 mm², shows great differences in various species of amphibians. It ranges from 14–16 meshes/1 mm² in Rhyacotriton olympicus (Czopek, 1962) to over 300 meshes/1 mm² in Bufo cognatus and B. compactilis (Bieniek and Watka, 1962).

The capillary density varies with both the developmental stage and the body weight of the specimens. In Ambystoma mexicanum (Czopek, 1957) and Salamandra salamandra (Czopek, 1959) the number of meshes per 1 mm² in the palate is much smaller in larvae (22 and 20 respectively) than in metamorphosed specimens (81 and 50 respectively). Similar findings are reported in juvenile R. temporaria, R. terrestris and Hyla arborea (Andrzejewski and Maciaszek, 1960).

The length of the capillaries in the oral mucosa of amphibians per unit of body weight ranges from 0.03 m/g (Xenopus laevis) to 1.9 m/g (Acris crepitans) (Czopek, 1965). The percentage contribution of these vessels to the total surface area of the respiratory vessels distributed in the skin, lungs and in mucosa of the oral cavity is low in the majority of amphibians. Its role in respiration is estimated as about 1–3%. In lungless Plethodontide it may reach a higher value, 5–10% (Czopek, 1959, 1961). According to the respirometric measurement of Whitford and Hutchinson (1965) in plethodontid salamanders the buccopharyngeal cavity may account to 24% of the total oxygen uptake.
The quantity of the diverticula of the capillaries in the amphibian oral mucosa is similarly variable. They are absent in Siren intermedia, Diemictylus viridescens, Amphiuma means, Leiopelma hochstetteri and in the larvae of Ambystoma mexicanum and Salamandra salamandra (Czopek, 1957, 1959, 1962, 1965). Some diverticula occur in Bombina bombina, Triturus vulgaris, Scaphiopus holbrooki and S. couchi, but they increase the total surface area of the oral capillaries only by a few percent (Czopek, 1955, 1959; Czopek et al., 1968). Nevertheless, in R. terrestris, adult S. salamandra and A. opacum as well as in some Plethodontidae, numerous diverticula increase the surface area of the respiratory capillaries by about 10% (Czopek, 1955, 1959, 1962). In Bufo bufo and Hyla arborea the presence of diverticula is reported to increase the surface area of the oral vessels by more than 100% (Czopek, 1955). On the other hand, the smaller number of diverticula in the oral vessels of Bufo viridis, B. calamita, Triturus vulgaris and Desmognathus fuscus is compensated by the tortuous course of these vessels, which doubles their surface area (Czopek, 1959, 1961, Czopek and Czopek, 1959). A similar result could be obtained by an appropriate increase in the diameter of the capillaries as reported in Diemictylus viridescens (Czopek, 1962).

Some authors have expressed doubts about the involvement of the oral mucosa of amphibians in gas exchange (Alexander, 1975). The oscillatory movements of the bottom of the oral cavity are purported to be related to olfaction rather than respiration (Elkan, 1955). However, the quantitative data presented above as well as knowledge of the morphology and topography of the capillaries in different species of amphibians together with the results of respirometric measurements in plethodontid salamanders (Whitford and Hutchison, 1965) support the assumption of a respiratory role for those vessels. It is also noteworthy that the involvement of different respiratory organs in gas exchange, such as the lungs, skin and possibly the oral mucosa shows a differing relative importance with variations of ambient temperature. Hutchison et al. (1968) have shown experimentally that in Bufo terrestris at low ambient temperatures (5°C) the diffusion of oxygen in the skin is greater than in the lungs. At higher ambient temperatures this dependence is reversed and the diffusion of oxygen is greater in the lungs than in the skin. The carbon dioxide excretion also depends on temperature, but the intensity of this process is greater in the skin than in the lungs both at low and high ambient temperatures.

The increase in the capillary surface area can be accomplished by: 1) an increase in capillary length per unit of surface or per unit of body weight; 2) an increase in capillary diameter; and exceptionally 3) by folding of the endothelial cells lining the capillary lumen. The latter case has been found in conus papillaris in reptiles as well as in the pecten oculi in birds (Dieterich et al., 1976; Dieterich and Dieterich, 1977; Jasiński, 1973, 1977). A similar effect attained by the formation of blind diverticula in the vessels is really unique. This device has been found exclusively in the capillaries of amphibian oral mucosa. The fine structure of these capillaries and the rheological role of their diverticula in the blood circulation remain to be elucidated.

Acknowledgement. We should like to thank Mrs. A. Friedhuber and Mrs. A. Kubiena for their skillful assistance during this investigation.
REFERENCES


Dr. Adam Miodoński
Department of Neuroanatomy
Institute of Zoology, Jagiellonian University
M. Karasia 6, 30–060 Krakow, Poland