

## Regulation of nasal heat exchange in reindeer

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Previous studies have shown that reindeer are able to restrict respiratory heat loss by use of nasal heat exchange (Blix and Johnson, 1983). This mode of heat conservation, which is based on cooling of the expired air, and thereby condensation of water, particularly at low ambient temperatures, is possible because of the existence of a temperature gradient along the length of the nasal passages (Johnsen *et al.*, 1985a). Furthermore, Blix and Johnsen (1983) have shown that there is a summer to winter difference of about 12°C in exhaled air temperature at, for instance, -10°C ambient temperature, in these animals. At this ambient temperature respiratory minute volume and frequency were the same in summer and winter. This therefore indicates that the temperature gradient along the nasal mucosa in reindeer must be under physiological control.

We have recently investigated the vascular anatomy of the reindeer head with particular emphasis on the nasal mucosa. Based on ideas which emanated from this work we have put forward a hypothesis for the operation and control of nasal heat exchange in reindeer (Johnsen *et al.*, 1985a).

In order to visualize the vascular system of the reindeer head we have made use of uni-lateral plastic casts. These casts revealed that the nasal mucosa in reindeer consists of a network of frequently anastomosing arteries running the full length of the nasal turbinates in the anterior direction. This rete runs adjacent to and in close contact with a venous rete of similar complexity with which it communicates by way of capillaries

and arterio-venous anastomoses. It was also evident from the plastic casts that the effluent from the venous rete can be drained through the deep sphenopalatine group of veins at the posterior end, and through the superficial dorsal nasal vein at the anterior end of the nasal cavity. The dorsal nasal vein in turn has a possibility to drain either directly into the jugular vein via the facial vein, or to the carotid rete for selective cooling of the brain.

In situations of extreme heat conservation in the cold we suggest that the blood runs in opposite directions in the arterial and the venous rete of the nasal mucosa, whereby the temperature gradient along the nasal mucosa, which is necessary for cooling of the expired air, is maintained due to counter-current heat exchange. In this situation arterial inflow to the rete is low, and the dorsal nasal vein and the vessels of the anterior end of the venous rete are constricted. Accordingly, the venous effluent from the nasal mucosa is primarily drained through the sphenopalatine group of veins at a temperature close to that of the arterial blood.

On the other hand, when the animal is in a state of extreme heat dissipation (in a hot environment, or during running), respiratory minute volume will increase substantially (Blix and Johnsen, 1983). However, an increase in respiratory minute volume without circulatory adjustments, will result in a substantial decrease of nasal mucosal temperature and a subsequent reduction in expired air temperature, which would compromise the dissipation of heat by way of the respiratory tract. Under such heat

stress conditions we therefore suggest that concomitant with heat induced panting the arterial inflow to the nasal mucosa is increased. We moreover suggest that the arterio-venous anastomoses are open and that both retia are now perfused unidirectionally in the anterior direction, and that the venous effluent is drained primarily by way of the dorsal nasal vein while the sphenopalatine group of veins are constricted. It follows that the nasal mucosa may now be perfused counter-current with respect to the inspired air, and heat loss from the mucosal surfaces is thereby optimized. The venous effluent in the dorsal nasal vein will then be colder than the arterial blood, and may now be distributed either to the carotid rete for selective cooling of the brain, or, directly to the right atrium of the heart for general body cooling.

With the animal in a state between the above described extremes the need for accurate control of the temperature gradient along the nasal mucosa arises. Thus, changes in ambient temperature, metabolic heat production, respiratory minute volume and seasonal changes in fur insulation must be accounted for if fine tuning of thermal balance is to be achieved. In this respect we have previously found indications for an active regulation of the temperature gradient along the nasal mucosa in reindeer (Mercer *et al.*, 1985b).

Our results suggest several ways by which the temperature gradient along the nasal mucosa may be controlled. With the ventilatory volume kept at a constant level, the temperature gradient along the nasal mucosa may be changed in response to changes in the arterial inflow to the nose, and/or as a result of changes in the distribution of the venous effluent between the dorsal nasal and the sphenopalatine group of veins.

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