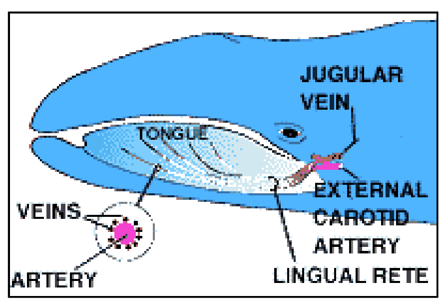
By Dr. John E. Heyning

A gray whale dives to the bottom of the shallow Bering Sea off the coast of Alaska, rolls on its side, and then opens its enormous mouth to suck up bottom sediments and the associated shrimplike crustaceans, called amphipods. Closing its mouth, the whale forces water and silt out through its filtering baleen and then feasts upon the amphipods, which remain behind.

The whale's filter feeding not only traps prey, but it also exposes the inner surfaces of the mouth to the frigid polar waters. Although a gray whale's blubber layer effectively insulates it in even the coldest of waters, its immense mouth lacks blubber. Feeding should cause these "warm-blooded" mammals to chill and eventually succumb to hypothermia after just a few meals.

This physiological dilemma is not restricted to gray whales but is shared by other species of baleen whales, which are members of the suborder Mysticeti: all have cavernous mouths to accommodate the maximum amount of baleen filtering surface, and most feed in the cold waters of high latitudes. How do these whales manage to maintain body warmth while feeding?



My study of this quandary grew from the simple observation of a unique pattern of blood vessels in a rare mysticete, the pygmy right whale (see Terra 34(4): 6-7). Scattered throughout the tongues of these relatively small baleen whales were a number of "countercurrent heat exchangers," each consisting of a single central artery encircled with a network of veins. A heat exchanger allows the transfer of heat from warm blood coming from the body core in the artery to the adjacent cooler blood returning from an extremity in the veins. Scientists have known for some time that the fins and flukes of whales and dolphins contain countercurrent heat exchangers, but the discovery of this heat-conserving feature in the tongue of a whale was surprising. I wondered if other baleen whales have these structures in their tongues.

The baleen whale most frequently stranded off southern California is the gray whale (Eschrichtius robustus), which migrates along our coastline from its winter mating and calving lagoons off the west coast of Baja California to its summer feeding grounds in the Bering and Chukchi seas. When a gray whale strands locally, its beach-cast carcass is usually transported to the museum's **Marine Mammal Laboratory** for careful dissection and preservation. In late 1996 and early 1997, my colleague Dr. James Mead and I dissected the vascular system of the tongues of two gray whales that had stranded.

The gray whale's tongue is massive, representing 5 percent of the entire surface area of its body. In the tongues of each of the two young calves we dissected we found numerous countercurrent heat exchangers, all converging at the tongue's base into a bilateral pair of bundles, each with over 50 heat exchangers in parallel arrangement. We called these bundles the lingual retia, or tongue network. The lingual retia of these whales are far larger than the heat exchangers associated with their fins and flukes.

In retrospect, it seems incredible that we cetacean anatomists could have overlooked such large and complex structures in previous dissections of baleen whales. Yet because the vascular system is composed of numerous small, thin-walled veins that easily collapse when the large, flaccid tongue is dissected, the lingual retia had escaped notice.

Jim Mead and I had found countercurrent heat exchangers in our tongue dissections, but we lacked the physiological proof that they actually worked to conserve body heat in gray whales. And proof seemed impossible to get: no baleen whales were held in captivity, and free-swimming gray whales were not likely to have much interest in allowing us to take temperatures readings from inside of their mouths.

Then a widely publicized event provided us with a once in a lifetime opportunity. In January 1997, an orphaned newborn gray whale was found off Marina del Rey. The museum's mammalogy staff helped in the rescue of the calf, which was taken to Sea World in San Diego. There, the youngsterÑwho was named JJÑthrived under expert care. And overnight, we had an opportunity to test our hypothesis.

Heat is transferred into or out of the body because of temperature differentials, and a comparison of a whale's skin surface temperature with the temperature of the surrounding water is a good indicator of heat loss: if there is little difference between the temperature of the skin and that of the water, it is a sign that little heat loss is taking place. On several occasions in spring and summer of 1997, I leaned over JJ's tank at Sea World with an infrared thermometer and took some measurements as she was fed.

As she suckled on her feeding tube, JJ needed to open her mouth to the water only a little way. After about 1 minute of feeding, the temperature of the surface of her tongue was a mere 1¡ Fahrenheit above that of the surrounding water, and 1¡ to 4¡ F below the temperature of her head and neck region.

Just as I had predicted, JJ was losing little heat through her tongue. Furthermore, her tongue remained a vivid pinkish color, indicating that the blood vessels there were not simply constricting to conserve heat. Our observations suggest that the lingual retia are extremely efficient: gray whales appear to suffer more heat loss through their body-encasing blubber layer than through the tongue, in spite of the fact that the tongue has far more blood vessels and possesses significantly less insulation.

I've reviewed the scientific literature and believe that countercurrent heat exchangers may be a universal feature in the mouths of baleen whales, although the vascular structures have never been identified as such in other dissections. Our findings suggest that, for all baleen whales, the mouth is a crucial site for the regulation of body temperature during filtration of their prey.

The development of countercurrent heat exchangers in the mouths of baleen whales is probably as important in their evolution as the development of the filtering baleen itself. These two structures have together allowed these mammals to exploit the high productivity of the ocean's coldest waters.

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