生物策略格式

KJC, 2019/10/21

類別	生物策略 (Strategy)
生物策略 STRATEGY	用鼻表面移除水汽 (Nasal surfaces remove water vapor)
生物系統 LIVING SYSTEM	單峰駱駝 *Camelus dromedaries* (Dromedary)
功能類別 FUNCTIONS	#獲取、吸收或過濾液體 #保護免受液體流失危害 #Capture, absorb, or filter liquids #Protect from loss of liquids
作用機制標題	透過鼻表面的吸濕特性去除空氣中的水分，有助於駱駝在呼氣過程中保存水分 (The nasal surfaces of camels help conserve water by using hygroscopic properties to remove water from air during exhalation.)
生物系統/作用機制示意圖	

作用機制摘要說明 (SUMMARY OF FUNCTIONING MECHANISMS)

當單峰駱駝在炎熱乾旱的環境中脫水時，鼻表面可採用兩種機制以協助其保留水分：夜晚時將呼出的空氣加以冷卻，以及從呼出的空氣中提取水汽。

夜晚時，外在的空氣通常低於駱駝的核心體溫。當駱駝吸氣時，外在的冷空氣經過鼻通道並在此進行熱交換：鼻表面被冷卻，同時流入的空氣被加溫。在駱駝肺臟中，空氣的溫度和體溫相同，且水分完全飽和（100%相對濕度）。當駱駝呼氣時，肺臟內的溫暖空氣經過冰涼的鼻表面，又再次進行熱交換。這次呼出的空氣被冷卻，且在冷卻時，排出空氣中的水汽會在鼻表面凝結成液態水。呼出的空氣仍然是 100%相對濕度，但較低的溫度表示有較多的水分以液態存在，而非氣態（解釋為何此處會發生此現象）。數種哺乳類與鳥類使用這種冷卻呼出氣體的機制，以保留水分和熱。

但單峰駱駝還使用第二種機制來保存更多的水分：從呼出的空氣中提取水汽，將其去飽和使相對濕度降低至 75%-80%。脫水的駱駝之乾燥鼻表面是吸濕的，意味著其能夠吸收並保留周遭的水分子。吸濕的鼻表面從呼出的空氣中吸收水分，並將水分送到吸入的空氣中。

單峰駱駝的水分回收機制能運作得如此有效率的一個原因，就是其鼻通道內具有龐大表面積的鼻甲骨結構。鼻甲骨為海綿狀的鼻骨，且駱駝的鼻甲骨是高度蜷曲的，可提供狹窄的空氣通道，以及水和熱交換的龐大表面積。測量數據顯示駱駝具有超過 1000 平方公分的鼻表面積，然而人類的鼻腔可能只有 160-180 平方公分的總表面積。

為何駱駝只在夜晚採用第一種機制來冷卻呼出的空氣？因為在炎熱的白天，避免腦部過熱將優先於保留水分。呼出溫暖又含飽和水汽的空氣，使得駱駝能夠排除身體多餘的熱

量，不過這是以付出保存的水分作為代價的。

When the dromedary camel gets dehydrated in its hot and arid environment, its nasal surfaces help the animal conserve water using two mechanisms: by cooling exhaled air during the night, and by extracting water vapor from exhaled air.

During the nighttime, outside temperatures are typically lower than the camel's core body temperature. When the camel inhales, the cool outside air passes through the nasal passages where heat is exchanged: the nasal surfaces are cooled while the incoming air is warmed. Inside the camel's lungs, air is at body temperature and fully saturated with water (100% relative humidity). When the camel exhales, the warm air inside the lungs passes over the cool nasal surfaces and exchanges heat again. This time, the air is cooled as it's exhaled, and as it cools, water vapor in the outgoing air condenses onto the nasal surfaces as liquid water. The exhaled air is still at 100% relative humidity, but the lower temperature means that more water exists in liquid form than in vapor form (read an explanation of why this occurs here). Several mammals and birds use this mechanism of cooling exhaled air to conserve water and heat.

But the dromedary camel uses a second mechanism to save even more water: it extracts water vapor from the exhaled air, desaturating it down to 75-80% relative humidity. The dry nasal surfaces of a dehydrated camel are hygroscopic, meaning they can absorb and hold onto water molecules from the surrounding air. The hygroscopic nasal surfaces absorb water from the exhaled air and give off water to inhaled air.

One reason these water recovery mechanisms work so effectively in the dromedary camel is the large total surface area of the turbinate structures in its nasal passages. Turbinates are spongy nasal bones, and the camel's turbinates are highly scrolled, providing narrow air passageways and a large surface area for water and heat exchange. Measurements suggest that camels have more than 1000 cm^2 of nasal surface area, whereas the human nasal cavity may have a total surface area of only 160-180 cm^2.

Why does the camel use the first mechanism and exhale cooled air only during the night? During the hot daytime, preventing the brain from overheating is prioritized over conserving water. Exhaling air that's warm and saturated with water vapor enables the camel to dump excess heat from its body, but this comes at the expense of saving water.

文獻引用 (REFERENCES)

「我們已經發現駱駝可以利用兩種方式來減少從呼吸道蒸發所造成的水分散失：(1)透過降低呼出空氣的溫度及 (2)透過去除呼出空氣中的水汽，使呼出空氣的相對濕度 (r.h.) 低於 100%。駱駝生活於沙漠環境中，且缺乏飲水。白天時其呼出的空氣與身體核心溫度接近或相同，而較冷夜晚時所呼出的空氣，則與周遭環境溫度接近或相同。白天時呼出的空氣濕度是完全飽和的，但夜間濕度可能下降至約 75% r.h.。相較於呼出和體溫相同的飽和空氣，冷卻與去飽和的組合則能提供 60%水分的保留。冷卻呼出空氣的運作機制，是呼吸氣體及鼻腔通道表面之間的簡單熱交換作用。在吸氣時，這些表面被流經的空氣所冷卻，在呼氣時，空氣中的熱則被送到這些較冷的表面。空氣的去飽和機制，似乎是依靠駱駝脫水

時鼻腔表面的吸濕特性。吸氣時，這些表面排出水汽，呼氣時則吸收水汽。我們使用了一個簡單機械模型來展示此機制的效能。」 (Schmidt-Nielsen and others 1981: 305)

"We have found that camels can reduce the water loss due to evaporation from the respiratory tract in two ways: (1) by decreasing the temperature of the exhaled air and (2) by removal of water vapour from this air, resulting in the exhalation of air at less than 100% relative humidity (r.h.). Camels were kept under desert conditions and deprived of drinking water. In the daytime the exhaled air was at or near body core temperature, while in the cooler night exhaled air was at or near ambient air temperature. In the daytime the exhaled air was fully saturated, but at night its humidity might fall to approximately 75% r.h. The combination of cooling and desaturation can provide a saving of water of 60% relative to exhalation of saturated air at body temperature. The mechanism responsible for cooling of the exhaled air is a simple heat exchange between the respiratory air and the surfaces of the nasal passageways. On inhalation these surfaces are cooled by the air passing over them, and on exhalation heat from the exhaled air is given off to these cooler surfaces. The mechanism responsible for desaturation of the air appears to depend on the hygroscopic properties of the nasal surfaces when the camel is dehydrated. The surfaces give off water vapour during inhalation and take up water from the respiratory air during exhalation. We have used a simple mechanical model to demonstrate the effectiveness of this mechanism." (Schmidt-Nielsen and others 1981: 305)

參考文獻清單與連結 (REFERENCE LIST)

Schmidt-Nielsen, K., R. C. Schroter, and A. Shkolnik. (1981). Desaturation of exhaled air in camels. *Proc. R. Soc. Lond.* 211: 305-319. (https://www.jstor.org/stable/35545?seq=1#metadata_info_tab_contents)

延伸閱讀:

生物系統延伸資訊連結 (LEARN MORE ABOUT THE LIVING SYSTEM/S)

https://en.wikipedia.org/wiki/camelus_dromedarius

文章貢獻/編修者與日期:

陳姿雅翻譯 (2019/05/21)；朱天愛編修 (2019/12/19)；吳晧編修 (2020/01/04)；
譚國鎏翻譯/編修 (2020/07/30)；紀凱容編修 (2020/11/26)；施習德編修 (2020/12/16)

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