Nautilus pompilius: Branchial circulation enhanced by an auxiliary pumping mechanism[1]

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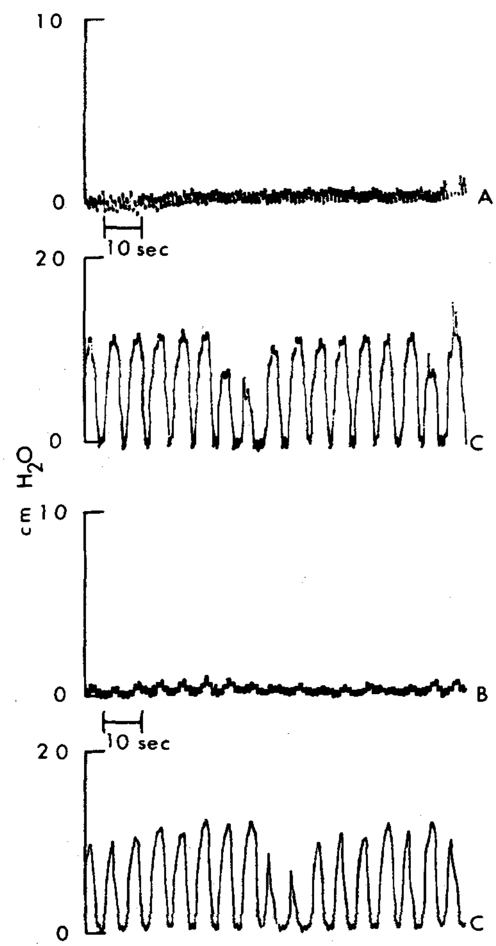
Summary. Blood pressure recordings from the vena cava, afferent branchial and efferent branchial veins in *Nautilus* showed that a significant increase in pressure of the gill circulation was achieved by the rhythmic contractions of the renal appendages and pericardial glands.

Since the time of Rumphius[3], zoologists and paleontologists have hoped that studies of living *Nautilus* would shed light on the biological interpretation of fossil nautiloids and ammonites and aid in the understanding of cephalopod evolution. In modern cephalopods, i.e. the existent coleoids, physiological investigations have established the important circulatory role of the branchial hearts[4–6]. Willey[7] first described the pulsations of the renal appendages and pericardial glands of *Nautilus*. Recently, Martin[8] suggested that the branchial hearts of the coleoids are derivatives of the pericardial glands of *Nautilus*. During a recent scientific expedition to the Philippines we studied *Nautilus pompilius* circulatory physiology to ascertain whether a special branchial blood pumping mechanism homologous to that of modern cephalopods exists.

Materials and methods. *Nautilus* captured by traps set deep (ca. 200 m) in Tañon Straits were purchased from local fishermen shortly after being brought to the surface and were maintained in cooled aquaria aboard the R/V 'Alpha Helix'. After animals were sufficiently relaxed by immersion in 5% urethane in seawater, polyethylene catheters were implanted into the right anterior afferent and efferent branchial veins and the venae cavae. Animals were returned to aquaria and permitted to recover. Following recovery, the catheters were attached to calibrated Statham p23 V blood pressure transducers coupled to a Beckman Dynograph 2-channel recorder. Blood pressure from the cannulated vessels was recorded in sequence pairing the 3 vessels in all combinations.



Blood pressure recorded from afferent and efferent branchial veins and vena cava of *Nautilus pompilius* No. 190. *A* Vena cava, *B* efferent branchial vein and *C* afferent branchial vein.

Results and discussion. Results presented here are from 3 animals; representative blood-pressure recordings from 1 animal (No. 190) are shown in the figure. Blood pressure in both the vena cava and efferent branchial vein was very low, occasionally becoming slightly negative. However, the pressure in the afferent branchial vein was higher; having a mean pressure of approximately 4.3 cm water with a systolic level of 10 cm water and a diastolic level of approximately 0 cm water. The pressure wave form of the afferent branchial veins has superimposed on it that of the vena cava. Additionally, the pulse rate in the afferent branchial vein was much lower than that of either the vena cava or the efferent branchial vein. The pulse rates, pressure levels and pressure wave forms in each of these three vessels were confirmed in 18 other experiments in which the sequence of recording from blood vessels was different[9]. When the pericardium was opened, both the pair of renal appendages and the pericardial gland located on the base of each afferent branchial vein were observed to contract in a rhythmic manner. These data and observations indicate that contractile structures located between the vena cava and efferent branchial veins are elevating the blood pressure and that these structures are likely the renal appendages and pericardial glands.

These results suggest that the development of a branchial circulatory pump was an ancient feat in the cephalopods. In *Octopus dofleini* the pressure developed by the branchial heart is important in producing an ultrafiltrate during urine formation[8] as well as pumping blood through the gills[6].

Although the gross anatomical appearance of the coleoid branchial heart and its appendage differs considerably from their pericardial gland precursor, the original excretory-circulatory dual function has been retained.

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