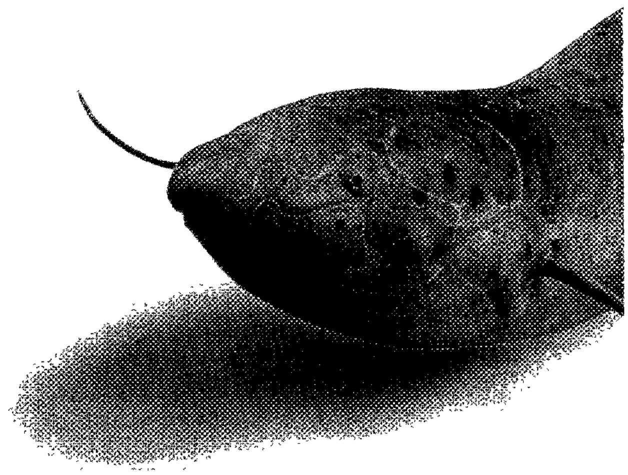
AND THE BEAT GOES ON

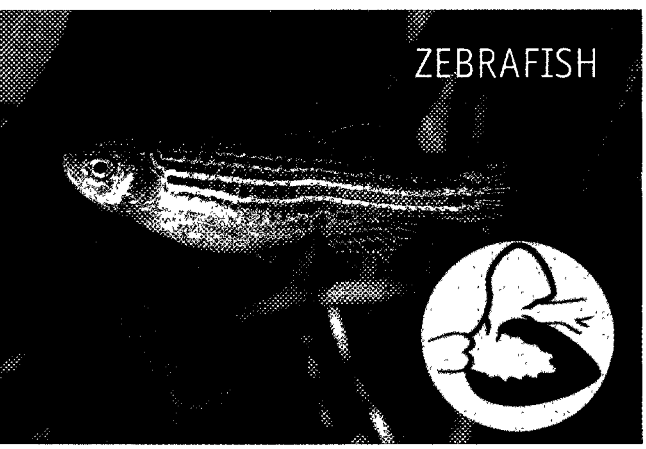
A BRIEF GUIDE TO THE HEARTS OF VERTEBRATES

BY WARREN BURGGREN



HEART DIAGRAMS BY UTAKO KIKUTANI

Biologists would love to know just how the vertebrate heart evolved from the simple, two-chambered organ of early fish to the complex, multichambered hearts of birds and mammals, with their two atria (which receive blood from the veins) and two ventricles (which pump blood back out through the arteries). Unfortunately, soft tissues rarely make good fossils, so we are unlikely ever to know for certain. But we can construct a hypothetical scenario by looking at the wide variety of hearts found in animals alive today. Amphibians, reptiles, birds, and mammals have been following independent evolutionary paths for millions of years, of course, and no modern biologist would dare suggest

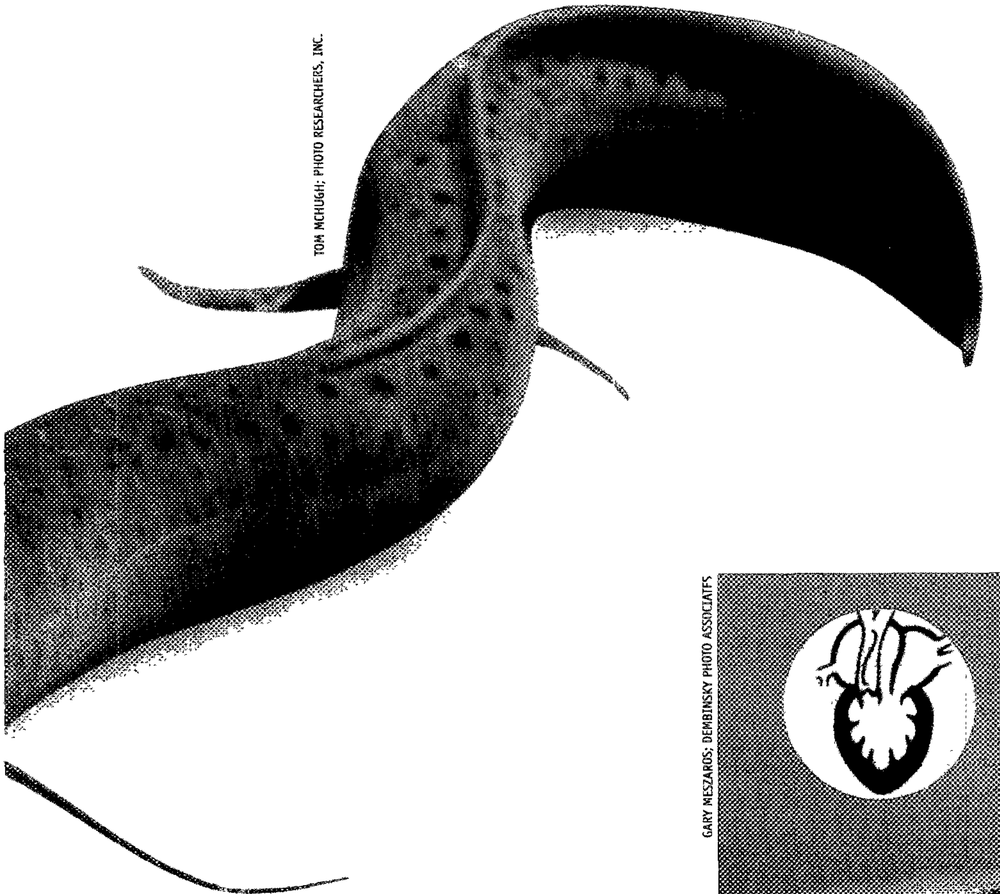


MARK SMITH; PHOTO RESEARCHERS, INC.

that a frog or alligator is a step en route to an eagle or human being. However, comparing the hearts of living vertebrates—and specifically how they handle the transport of oxygen to the body's tissues (one of the organ's most important functions)—can provide insights into what the intermediate steps between one type of heart and another might be.

We start with the heart found in most fish today: a relatively simple organ, with one atrium, from which blood flows into a single ventricle. After leaving the heart, blood picks up oxygen at the gills, but by the time the blood returns to the heart, most of its oxygen is gone. With the evolution of lungs came a partial separation of oxygenated from deoxygenated blood, ensuring a steady supply of oxygen to the heart and its more efficient distribution to the rest of the body. The division of the atrium into two chambers—evident in living lungfish—was an important step toward more complete separation.

In the the heart of modern frogs and toads, we see the beginnings of distinct ventricular chambers as well. Although these animals have only one ventricle, its spongy walls help separate oxygenated and deoxygenated blood: oxygen-rich blood flowing in from the left atrium tends to get soaked up by the left ventricular wall; oxygen-poor blood from the right atrium is taken up by the right wall. When the amphibian ventricle contracts, it expels all the blood into a central artery, where the two flows are again kept largely separate by a long winding valve that spirals down the length of the artery, functionally dividing it into two channels. Most of the poorly



TOM MCHUGH; PHOTO RESEARCHERS, INC.

AFRICAN LUNGFISH

GARY MESZAROS; DEMBINSKY PHOTO ASSOCIATES

oxygenated blood travels through the channel that leads toward the lungs and skin, where it picks up a fresh supply of oxygen (in amphibians, the skin also functions as a gas-exchange organ). Most of the oxygenated blood ends up in the channel that leads out to other tissues in the body, providing them with nourishment. Partial division of the ventricle can be seen in the lesser siren *(Siren intermedia),* a salamander with a ridge of muscle rising up from the floor of the ventricle.

Division of the ventricle into more than one chamber is more complete in turtles, tortoises, and snakes. In addition to two atria, these reptiles have a three-chambered ventricle, however, and so don't fit neatly on our hypothetical continuum. Enter the varanids, or monitor lizards, a group that includes the huge Komodo dragon of Indonesia. Like those of other reptiles, the varanid's heart has a total of five chambers, but one of the ventricles is little more than a small pathway for the blood that traverses the heart. There is still some mixing of oxygenated and deoxygenated blood from the other two, larger ventricular chambers but much

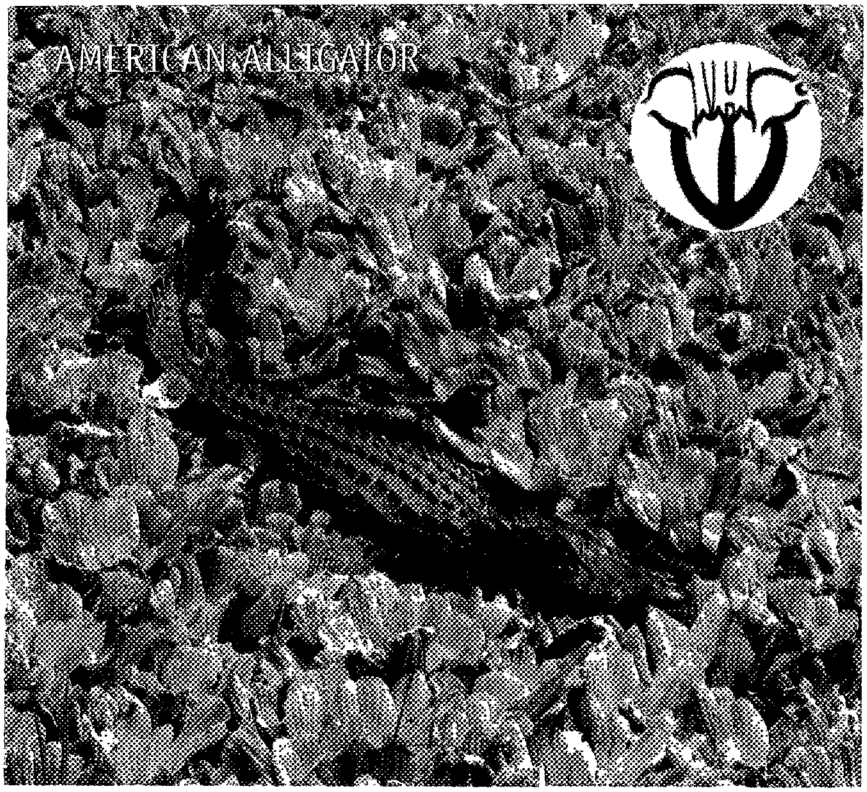
JOE MCDONALD; BRUCE COLEMAN, INC

less than occurs in the heart of a turtle or snake.

The varanid heart introduces, for the first time, a way to deal with a vital but potentially dangerous component of the circulatory system: blood pressure. High blood pressure helps the heart pump harder to deliver more blood more quickly to working muscles and other tissues in the body. Unfortunately, these same pressures can "blow out" the lung's delicate vessels, which operate most effectively at lower blood pressures. With its two nearly separate ventricular chambers, the varanid heart can pump at two different pressures: low for blood to the lungs, high for blood heading out to the rest of the body. Perhaps not surprisingly, this efficient heart enables some of the monitor lizards to be truly frightening predators, able to capture very active prey.

THE COMPLETELY DIVIDED HEARTS OF BIRDS AND MAMMALS CAN PUMP BLOOD HARD AND FAST TO WORKING MUSCLES AND MORE GENTLY TO DELICATE LUNG MEMBRANES.

FRITZ POLKING; PETER ARNOLD, INC.



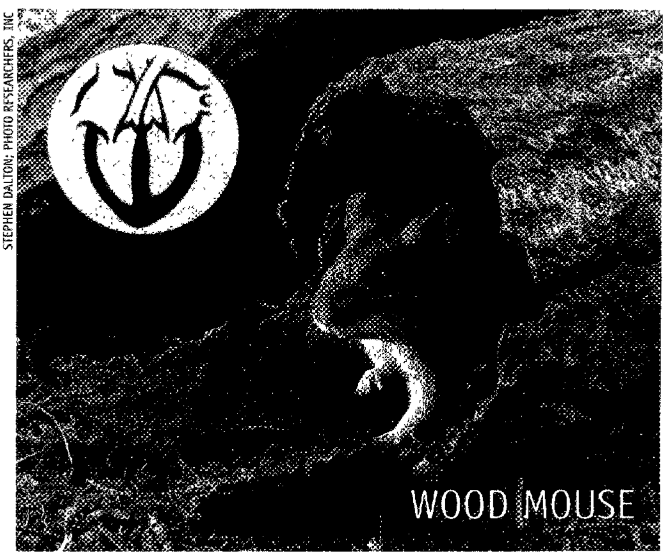
We turn next to crocodiles and alligators, in which the heart has two anatomically separate ventricles. When breathing air at the water's surface, these reptiles, like monitor lizards, pump blood at two different pressures. Once they slip beneath the surface, however, they do not breathe, and their hearts produce a single, intermediate pressure. While underwater, crocodiles and alligators perform another neat heart trick: blood that would have gone to their lungs (which become less useful during a dive, as their oxygen is depleted) is shunted, via an extra aorta emerging from the right ventricle, back toward the general body circulation.

In birds and mammals, the separation of the left and right sides of the heart is complete. This allows for high-pressure distribution of blood to the body, with no risk to delicate lung membranes. (For diving birds and mammals, this is a mixed blessing. Whether resting on the beach or diving for food [when the lungs are not ventilated], a seal or penguin must pump the same amount of blood both to its lungs and to the rest of its body.)

The next steps on our hypothetical continuum have yet to be determined. The human heart is no more the ultimate in cardiac design than was that of reptiles before mammals evolved. Perhaps in the future, our descendants will inhabit other parts of the solar system. Could the vertebrate heart evolve to handle life on a planet with less gravity or less oxygen than we have on Earth? Or with more? If not, space colonizers will have no choice but to recreate Earth's environment wherever they go.

Warren Burggren, a biologist, is dean of the College of Arts and Sciences at the University of North Texas.

ROLAND SEITRE; PETER ARNOLD, INC



STEPHEN DALTON; PHOTO RESEARCHERS, INC