

qualitative adjustment. Rhea heart mass (267 grams) conforms to that predicted for a mammal of the same body size and aerobic power. Volume densities of mitochondria in leg muscles are similar to those of mammals of the same size and aerobic capacity, whereas those in the relatively inactive flight muscles are only half as large and correspond to values reported for less aerobic mammals (Table 1).

Given that 30% of the rhea's body mass consists of leg musculature, rates of oxygen uptake by mitochondria per millilitre during locomotion at the aerobic maximum appear to fall within the range reported for mammals. Capillary densities in the rhea leg and flight muscles, like the mitochondrial volume densities, also parallel values reported for the muscles of athletic and less mobile mammals.

In contrast to the apparent conservation of structure-function relationships in most of the respiratory system, our results suggest that there are basic differences in the performance of the lungs of birds and mammals. We could not measure the lung volumes of the rheas directly, but in birds these are normally slightly more than half of those of mammals of the same mass^{7,8}. The rheas therefore achieved maximum oxygen flux rates, equal to those of the most aerobic mammals of their size, using lungs that are probably only half as large. This supports the general belief that avian lungs provide relatively more function per unit volume than mammalian lungs^{8,9}.

Although the aerobic limits of rheas and athletic mammals are similar, the metabolic power available in practice, and their functional needs, are not. Unlike dogs, horses and other athletic mammals that sustain high metabolic rates for hours during predation and migration, rheas do little or no sustained running and are poor at dissipating metabolic heat loads¹⁰. Rheas have apparently not been under strong selective pressures like those that promoted the aerobic power of extant running mammals. Large flightless birds lead fairly inactive lives, and may have lost the ability to fly primarily because of a lack of predation. Why rheas have an aerobic power that greatly exceeds their apparent functional needs remains a puzzle.

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The Thomas Jefferson paternity case

The DNA analysis of Y-chromosome haplotypes used by Foster *et al.*¹ to evaluate Thomas Jefferson's alleged paternity of Eston Hemings Jefferson, the last child of his slave Sally Hemings, is impressive. However, the authors did not consider all the data at hand in interpreting their results.

No mention was made of Thomas Jefferson's brother Randolph (1757–1815), or of his five sons^{2,3}. Sons of Sally Hemings conceived by Randolph (or by one of his sons) would produce a Y-chromosome analysis identical to that described by Foster *et al.* Further collaborative data (for example, the whereabouts of any of those who might have been involved at conception) are needed to confirm that Jefferson did indeed father his slave's last child, as claimed in the title. We know Thomas Jefferson was there, but how about Randolph Jefferson and his sons?

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If the data of Foster *et al.* are accurate, then any male ancestor in Thomas Jefferson's line, white or black, could have fathered Eston Hemings. Plantations were inbred communities, and the mixing of racial types was probably common. As slave families were passed as property to the owner's offspring along with land and other property, it is possible that Thomas Jefferson's father, grandfather or paternal uncles fathered a male slave whose line later impregnated another slave, in this case Sally Hemings. Sally herself was a light mulatto, known even at that time to be Thomas Jefferson's wife's half sister^{3,4}.

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Foster et al. reply — It is true that men of Randolph Jefferson's family could have fathered Sally Hemings' later children. Space constraints prevented us from expanding on alternative interpretations of

our DNA analysis, including the interesting one proposed by Davis. The title assigned to our study was misleading in that it represented only the simplest explanation of our molecular findings: namely, that Thomas Jefferson, rather than one of the Carr brothers, was likely to have been the father of Eston Hemings Jefferson.

It had been suggested to us earlier (by Herbert Barger, who also helped to recruit the descendants of Field Jefferson who participated in our study) that Isham Jefferson, son of Thomas Jefferson's brother Randolph, might have been the father of one or more of Sally Hemings' children. Barger's proposal was based on a statement⁵ that Isham was reared by Thomas Jefferson; he suggested that Isham could have been at Monticello or at Snowden (Snowden was across the James River from Scottsville, which is about 20 miles from Monticello) when Eston Hemings was conceived. But it is not known for certain that Isham was at Monticello at that time, whereas it is documented that Thomas Jefferson was. From the historical knowledge we have, we cannot conclude that Isham, or any other member of the Jefferson family, was as likely as Thomas Jefferson to have fathered Eston Hemings.

We know from the historical and the DNA data that Thomas Jefferson can neither be definitely excluded nor solely implicated in the paternity of illegitimate children with his slave Sally Hemings. When we embarked on this study, we knew that the results could not be conclusive, but we hoped to obtain some objective data that would tilt the weight of evidence in one direction or another. We think we have provided such data and that the modest, probabilistic interpretations we have made are tenable at present.

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