Horsepower from a horse

Sir — Recent studies of flying animals carrying loads and of skeletal muscle in vitro subject to cyclic motions suggest that the maximum sustainable mechanical power output of muscle is 100–200 W. Given an animal’s size and its proportion of muscle mass, it is thus possible to calculate an upper limit to an animal’s power output. This led us to wonder how much horsepower one horse can actually produce.

The body mass of horses varies from less than 100 kg for ponies to more than 800 kg for large draught animals. According to Munro, skeletal muscle for a horse is about 45 per cent of the total mass, but we estimate that only 30 per cent could be used for mechanical work at any one moment. Assuming a mass-specific rate of 100 W kg⁻¹ of muscle and a body mass of 600 kg, one horse could, in theory, produce 18,000 W or, since one horsepower (HP) equals 746 W, about 24 HP! Is it possible that one horse generates that much horsepower? The assumptions, in the worst-case, might inflate the result by a factor of 2, yet this still gives an estimate of about 12 HP. This raises the question: was the definition of horsepower based on a lower rate of work, or can a healthy horse actually produce more than 10 HP?

As to the first possibility, it was James Watt himself who defined horsepower. According to Dickinson, in the early 1780s Boulton and Watt were manufacturing rotary steam engines that replaced horse power. Quite naturally, payments for the engine was an annual premium based on the number of horses needed to do the equivalent amount of work. In discussions with millwrights, Watt learned that during a day’s work a horse would walk an average of two and a half times per minute around a 24-ft diameter mill wheel. Dickinson (p. 145) says Watt assumed a horse exerted a tractive effort of 180 pounds force (lbf), yielding a power estimate of 33,929 ft-lbf min⁻¹ (1 horsepower = force × distance/time). In Watt’s plotting and calculation book this number was rounded to 33,000 ft-lbf min⁻¹, equivalent to the more familiar designation of HP for 550 ft-lbf s⁻¹.

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Hox genes, fin folds and symmetry

Sir — Tabin and Lauber suggest an evolutionary explanation of the similarity between tetrapod fore and hind limbs in which the Hox gene-regulated limb pattern originated in the pelvic appendage, and subsequent ectopic activation imposed the regulation and resultant homeotic transformation on the ancestral pectoral fin/fore limb. I agree with the general proposal that patterns of genetic regulation provide a new level of explanation for homology, but I question Tabin and Lauber’s specific evolutionary hypothesis.

The ‘pelvic before pectoral limb’ evolutionary model is based partly on the continuous lateral fin-fold theory of the origin of paired vertebrate appendages.

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