Animals are better sprinters than humans

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An interdisciplinary group of scientists from the universities of Cologne, Koblenz, Tübingen, and Stuttgart has studied the characteristics determining the maximum running speed in animals. The model they developed explains why humans cannot keep up with the fastest sprinters in the animal kingdom. Based on these calculations, the giant spider

Shelob from "The Lord of the Rings" would have reached a maximum speed of 60 km/h.

Many four-legged mammals can reach considerably higher running speeds than two-legged humans. Animals perfectly adapted to sprinting, such as cheetahs or antelopes, are characterized by a slender body shape, long legs, and a particularly mobile spine to achieve very high speeds when running. An interdisciplinary team including researchers at the University of Cologne's Institute of Zoology has now developed a model that takes these characteristics into account and can calculate the maximum running speeds for animals of any size. The results of their research have been published in the article "Rules of nature's Formula Run: Muscle mechanics during late stance is the key to explaining maximum running speed" in the *Journal of Theoretical Biology*.

The Tokyo Olympics are just around the corner, and one of the highlights will be the men's 100-meter sprint. Top sprinters can reach running speeds of almost 45 km/h. That sounds impressive, but actually is not when compared to sprinting performance in the animal kingdom. It is only roughly equivalent to the top speed of a domestic cat. Cheetahs can run more than twice as fast (over 100 km/h), but other animals such as antelopes (90 km/h), or even warthogs and hares (just under 60 km/h) would outrun human sprinters.

The research team led by Dr. Michael Günther (University of Stuttgart) investigated the physical and biological factors on which the top speed of these animals depend. In the process, the researchers developed comprehensive answers to questions about the importance of body design, such as: "Why are natural maximum speeds achieved by medium-sized animals?" "Which main characteristics determine the maximum running speed?" and "What characteristics set limits to speed?"

The core of their theoretical work is the physical balance of propulsive

leg force and air resistance to be overcome, as well as the inertia of the propelling muscles. They show a kind of main pathway for changing the structural shape of animal bodies as a function of body size (allometry) in adaptation to fast leg-driven locomotion. "This main pathway describes how the shape of an organism must change as a function of body size in order to achieve a high running speed, and how specific shapes affect the maximum speed that can be achieved," said Dr. Tom Weihmann from the University of Cologne's Institute of Zoology.

The classic example is the mouse and the elephant. An elephant-sized mouse would simply not be viable because its bones would break under their own weight. Elephants have much thicker and heavier bones relative to their weight as well as much longer and more straightened legs. These features make the enormous size of the animals possible. However, heavy bones and straight legs limit their top speed, which is much lower than that of cheetahs—even though elephant legs are much longer.

However, top speeds depend not only on size but also on construction, such as the number of legs and the mobility of the spine. For example, many four-legged mammals are able to reach much higher running speeds than bipedal designs such as humans and birds because they can gallop, using their trunk muscles for propulsion. "If the animals become too heavy, however, even more powerful muscles won't help because larger muscles take more time to contract at top speed. Accordingly, the weight limit above which sprinting speeds start to decrease again is around 50 kg, which is fairly close to the average weight of cheetahs and pronghorns, the fastest sprinters on our planet," Weihmann explained.

The model can even be applied to fantasy creatures. For example, the giant spider Shelob from J.R.R. Tolkien's "The Lord of the Rings' would be able to reach a top speed of about 60 km/h. In terms of human body geometry, the model shows that top sprinters in sports are already very

close to their speed optimum. Apart from technical applications like special running shoes or exoskeletons, providing lengthening levers or additional elasticity, only longer legs or more elastic tendons would allow even higher speeds.

More information: Michael Günther et al, Rules of nature's Formula Run: Muscle mechanics during late stance is the key to explaining maximum running speed, *Journal of Theoretical Biology* (2021). DOI: 10.1016/j.jtbi.2021.110714

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