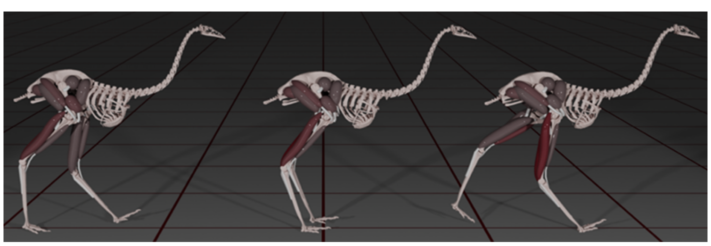
Why Emus Favor Fast Walking

Emus inherited from their dinosaur ancestors a crouched posture that dictates the gait they adopt when moving quickly, according to a new computer simulation of bird motion.

By **Charles Day**

Racewalking is a popular sport that has been part of the Olympics for more than a century. To avoid disqualification, racewalkers must ensure that the toe of their back foot remains in contact with the ground until the heel of their front foot has landed. The rule prevents racewalkers from adopting a more economical gait: running. Running owes its efficiency to lower muscle motion and higher use of energy stored in tendons. That mechanical advantage might seem universal, but ostriches, emus, and other long-legged flightless birds keep both feet on the ground until they reach sprint speed. For those birds, grounded running is evidently optimal, but why? Now Pasha van Bijlert of Utrecht University, Netherlands, and his collaborators have tackled the question by building and observing a virtual emu [**1**]. The answer, they conclude, lies in the anatomical constraints that arise from the crouched posture adopted by emus and other birds.

If an emu's grounded running is optimal, what factors are optimized? One contender is the metabolic cost of transport (MCOT), which is the energy consumed in moving, measured in joules per kilogram per meter (J/kg/m). The MCOT can explain why humans alternate between walking and running. If a person gets on a gradually accelerating treadmill, he or she will likely start out walking, as the MCOT is lower for walking than running at slow speeds. But once the treadmill reaches 9 km/h (where the MCOT is about 2.8 J/kg/m), the person will naturally switch to a run, as walking becomes increasingly less economical than running. But MCOT takes no account of fatigue—that is, how some motions can overwork particular muscles. A canoeist, for example, would tire faster than a single sculler rowing at the same speed because canoeists mostly work their arms, whereas rowers also use their legs and back muscles to propel their boats forward.



The virtual emu's gait is determined by its anatomy and by signals that direct its muscles. The signal sequence is iteratively optimized, resulting in an efficient and natural-looking gait.
Credit: Credit: V. Bijlert *et al.*, Sci. Adv. 10, eado0936 (2024)

To explore the possible roles of MCOT and fatigue in determining an emu's gait, van Bijlert and his collaborators created a virtual emu. Derived from computed tomography scans of an emu skeleton, the virtual bird was divided into nine body segments. The researchers fleshed out the body with 18 groups of virtual leg muscles.

The muscles were set in motion by virtual nerve signals, whose onset times were free to vary. Van Bijlert and his collaborators set out to find sequences of signals that led to a steady, periodic gait while also minimizing MCOT and fatigue. To do so, they turned to a computational approach that aerospace engineers use to optimize the trajectories of multistage rockets. From a set of initial conditions, the optimizer iteratively adjusted the signal sequences. Initially, it ignored some physical constraints, such as the requirement that the virtual emu obey the laws of classical mechanics. Eventually, the optimizer converged to minima that satisfied all the physical constraints.

One of those constraints was the bird's standing posture. When birds stand, they crouch to position their center of mass above their feet. That posture stems from birds' dinosaur ancestors, who had relatively long tails that offset the weight of their forward-leaning upper torsos, necks, and heads. As the ancestors' tails evolved to become lighter and more feathered and as musculature required for flight became bigger and heavier, their center of mass shifted closer to the animal's head, necessitating a crouched posture to remain balanced. Van Bijlert and his collaborators found that their virtual emu's crouched posture dictated that grounded running is the optimal gait, meaning it minimized MCOT and fatigue.

Biophysicist Emanuel Andrada of Friedrich Schiller University Jena in Germany points out that the horizonal trunk and crouched posture of birds have long been puzzling, given the anthropocentric presumption that the vertical trunk and upright posture of humans are optimal. Yet birds, who make up most of Earth's bipedal species, have retained their posture for 240 million years. He and others have identified specific factors, such as a requirement to minimize joint rotation, which account for that persistence. Van Bijlert and his collaborators' simulations help complete the picture by bringing together bird posture and bird motion, Andrada says.

Charles Day is a Senior Editor for ***Physics Magazine***.

REFERENCES

1. P. A. van Bijlert *et al.*, "Muscle-controlled physics simulations of bird locomotion resolve the grounded running paradox," **Sci. Adv. 10 (2024).**