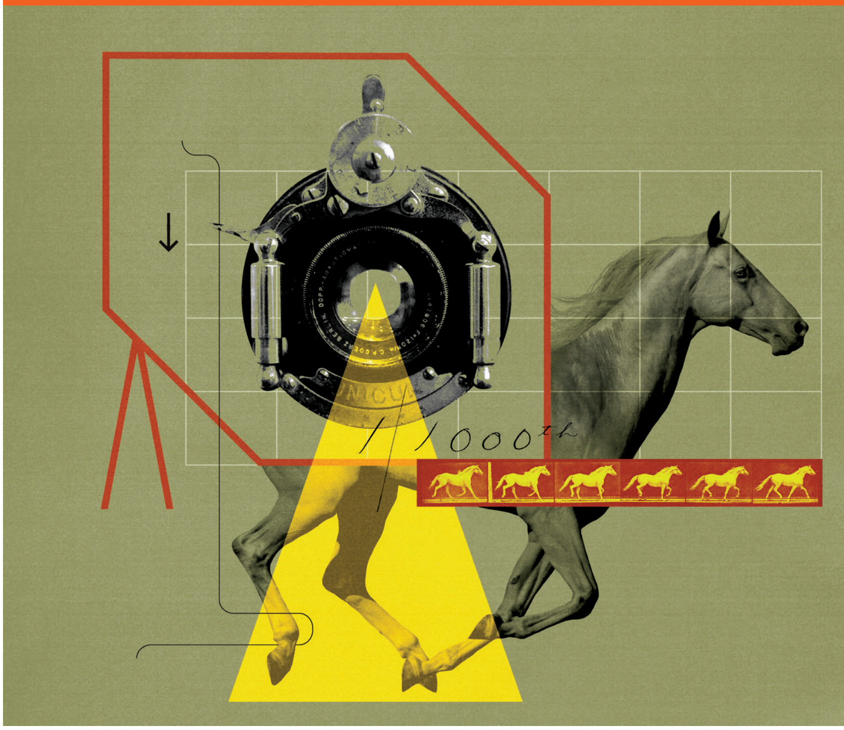

JUNE 1878: MUYBRIDGE'S GALLOPING HORSE

EADWEARD MUYBRIDGE (1830–1904), an English photographer, established his American fame in 1867 by taking a mobile studio to Yosemite Valley and producing large silver prints of its stunning vistas. Five years later he was hired by Leland Stanford, then the president of the Central Pacific Railroad, formerly the governor of California and latterly the founder of the eponymous university in Palo Alto. Stanford–who was also a horse breeder–challenged Muybridge to settle the old dispute about whether all four of a horse's legs are off the ground at one time during a gallop. ● Muybridge found it difficult to prove the point. In 1872 he took (and then lost) a single image of a trotting horse with all hooves aloft. But he persevered, and his eventual solution was to capture moving objects with cameras capable of a shutter speed as brief as 1/1,000 of a second. ● The conclusive experiment took place 141 years ago, on 19 June 1878, at Stanford's Palo Alto farm. Muybridge lined up thread-triggered glass-plate cameras along the track, used a white-sheet background for the best contrast, and copied the resulting images as simple silhouettes on a disc rotating in a zoopraxiscope, a device he invented in order to display a rapid series of stills to convey motion. Sallie Gardner, the horse Stanford had provided for the test, clearly had all four hooves off the ground. But the airborne moment did not take place as portrayed in famous paintings, perhaps most notably Théodore Géricault's *1821 Derby at Epsom*, now hanging in the Louvre, which shows the animal's legs extended, away from its body. Instead, it occurred when the horse's legs were beneath its body, just prior to the moment the horse pushed off with its hind legs. ● This work led to Muybridge's magnum opus, which he prepared for the University of Pennsylvania. Starting in 1883, he began to make an extensive series depicting animal and human locomotion. Its creation relied on 24 cameras fixed in parallel to the 36-meter-long track and two portable sets of 12 batteries at each end. The track had a marked background, and animals or people activated the shutters by breaking stretched strings.

The final product was a book with 781 plates, published in 1887. This compendium showed not only running domestic animals (dogs and cats, cows and pigs) but also a bison, a deer, an elephant, and a tiger, as well as a running ostrich and a flying parrot. Human sequences depicted various runs and also ascents, descents, lifts, throws, wrestling, dances, a child crawling, and a woman pouring a bucket of water over another woman.

Muybridge's 1,000 frames a second soon became 10,000. By 1940, the patented design of a rotating mirror camera raised the rate to 1 million per second. In 1999, Ahmed Zewail got a Nobel Prize in Chemistry for developing a spectrograph that could capture the transition states of chemical reactions on a scale of femtoseconds–that is, 10^{-15} second, or one-millionth of one-billionth of a second.

Today, we can use intense, ultrafast laser pulses to capture events separated by mere attoseconds, or 10^{-18} second. This time resolution makes it possible to see what has been until recently hidden from any direct experimental access: the motions of electrons on the atomic scale.

Many examples can be given to illustrate the extraordinary scientific and engineering progress we have made during the past 141 years, but this contrast is as impressive as any other advance I can think of–from settling the dispute about airborne horse hooves to observing flitting electrons. ■

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PHOTO-ILLUSTRATION BY Stuart Bradford