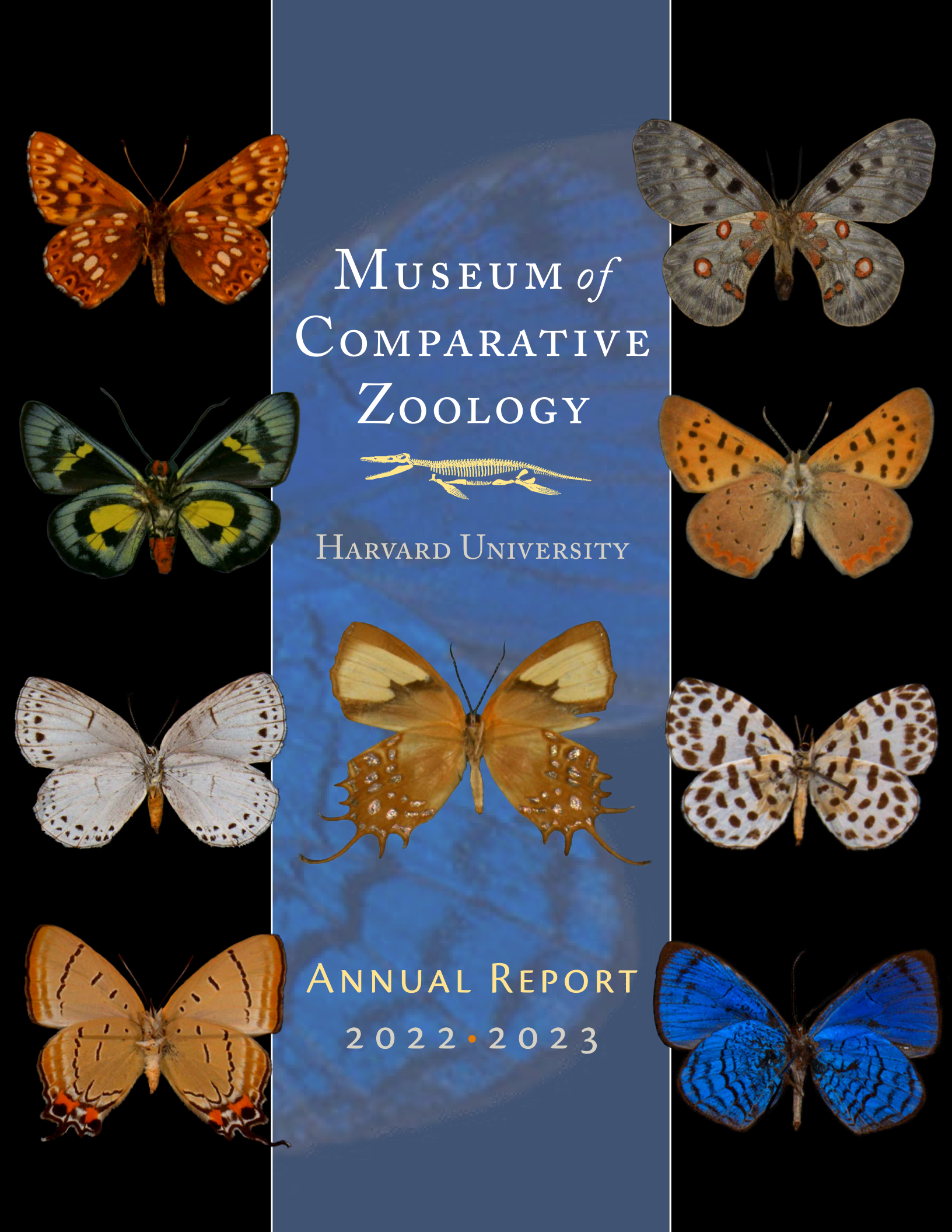


Museum of Comparative Zoology

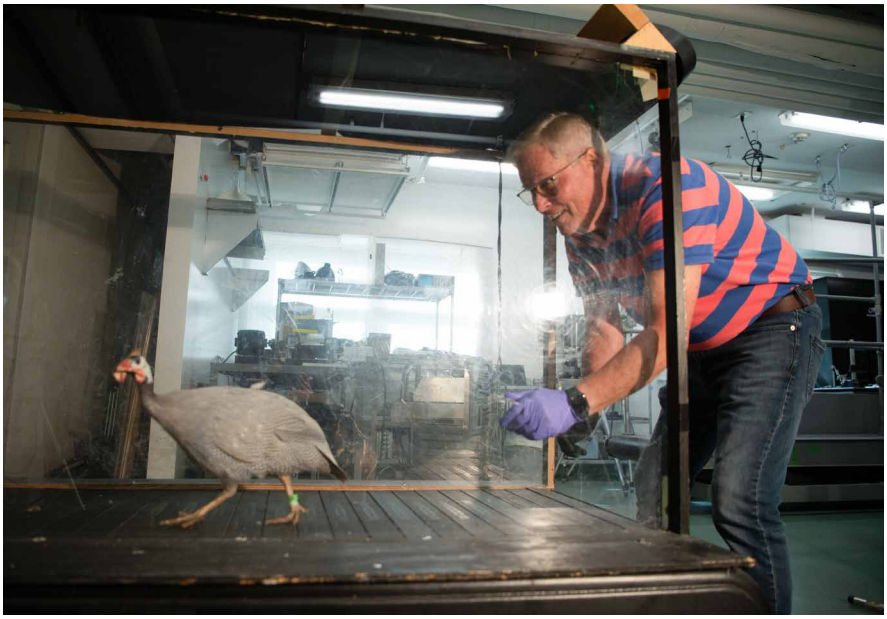
Harvard University

Annual Report

2022 • 2023

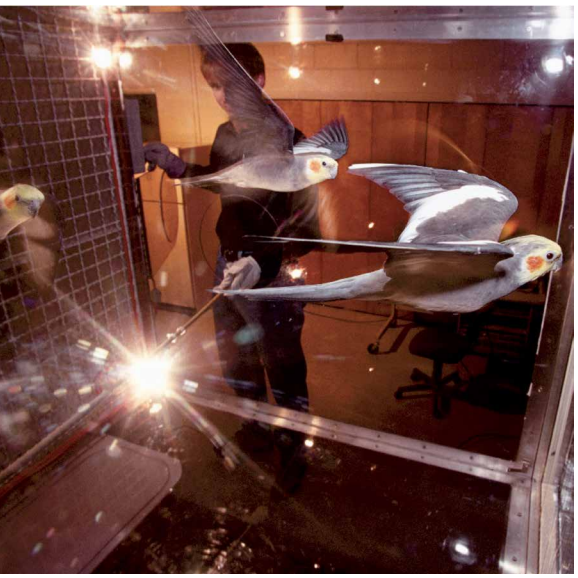
Decoding the Biology of Motion

Located 16 miles from Cambridge in Bedford, Massachusetts, the MCZ's **Concord Field Station** is a unique facility that is specially equipped to conduct comparative physiology and biomechanics research.



Dr. Andrew Biewener with a guinea hen on the treadmill. Photo by Melissa Aja

The station was established in the early 1960s and Dr. Charles P. Lyman, curator of Mammalogy, was acting director beginning in 1963. He was succeeded in 1969 by Dr. C. Richard Taylor, the first Faculty Director. Taylor studied mammalian environmental physiology and locomotor energetics and, continuing a series of firsts, was the first to train animals to run on treadmills and, together with his students, built the first treadmill with an integrated plate that could record the forces exerted by an animal's limbs while it was running. Other early laboratory work at the station included insect development and animal behavior, while field studies investigated plant life history strategies; resource allocation in plant populations; warbler vocalizations; and the study of local wasp, fungi, beetle and dragonfly species.



Ty Hendrick flies cockatiels in the wind tunnel (circa 2001). Photo by Jim Harrison

Dr. Andrew Biewener was appointed in 1998 as the second Faculty Director. "Despite working in very different fields, I always considered Andy a close MCZ colleague," says Gonzalo Giribet. "Since becoming director of the MCZ, I have enjoyed visiting the CFS and spending a little bit more time with him and witnessing the incredible research facility he has run so well and for so long. I'm looking forward to seeing how this incredible facility continues to be home for truly exciting research."

Biewener studies the neuromuscular control and biomechanics of animal movement on land and in the air. He was initially attracted to Harvard for multiple reasons—the legacy of research at the Concord Field Station, its excellent animal care facilities and the space to study large animals—but also because he could build a large-scale wind tunnel to study animals in flight.

A blueprint for this type of wind tunnel did not exist at the time, so Biewener and postdoctoral researcher Bret Tobalske designed it themselves and found a firm that supplied mine ventilation systems to provide the fan and motor assembly. When construction was completed in 2000, it was the only wind tunnel of its size dedicated to the study of animal flight in the United States, and it is still in use today. "Even now, there are probably no more than a half-dozen labs dedicated to examining animal flight with experimental aerodynamics—caring for animals in adjacent facilities, training them to fly in a wind tunnel, and filming their flight with high-speed, 3D video," says Biewener.

When an animal flies against the wind in the tunnel, the balance of forces results in a stationary state relative to the tunnel that allows researchers to film their flight for analysis. Researchers have trained a number of species to fly in this way, including bats and a variety of perching birds like cockatiels,

turtle doves, peach-faced lovebirds and zebra finches. “Generally,” Biewener explains, “one needs birds that are fairly smart and potentially a little more aggressive than birds like pigeons, which are notoriously bad at flying in wind tunnels. They just can't figure it out. Hummingbirds, however, hover and maneuver so naturally that they require no training at all.”

At 62 acres, the Concord Field Station is expansive. The main building consists of office space and two faculty laboratories—one for terrestrial locomotion studies and one for insect studies—with an adjoining animal care facility. The labs house three treadmills of various sizes, including the largest one with a force plate and an obstacle treadmill. The main building also has an electronics lab, a 3D-printing lab room and a surgical suite. Orthopedic studies have used the surgical suite to analyze the biomechanics of cartilage degeneration and hip loading/prosthesis design, using sheep as a model species. Indoor animal housing is supplemented with outdoor paddocks and animal shelters for a diverse range of insects and vertebrate species, including an emu that lived at the station for more than 20 years.

Biewener’s other major improvement to the station benefits not only research into animal movement, but also research in related fields. “Our videoradiography facility is where you can take high-speed X-ray movies of animals performing, whether they're feeding or flying or running,” he says. The 2D films can then be combined to create 3D images for analysis of musculoskeletal movements.

Over the years, Biewener and his lab members have used these tools to identify general principles governing the biomechanical and physiological design of vertebrate neuro-musculoskeletal systems. “This involves studies of how limb structure and function relate to animal movement across body size, gaits and mode of travel,” he says, “as well as how these relate to underlying neuromuscular, tendon and skeletal function.”

Dr. Andrew Biewener and his dog Lily at the wind tunnel. Photo by Melissa Aja

One of Biewener’s many memorable research efforts was a collaboration with MIT on the design of four-legged robots intended to climb and navigate rough terrain. This led to investigating how goats run so efficiently on rocky surfaces. The team even built a steep, 10-foot-high cinder-block hill with force plates to study the animals’ abilities as they scrambled to the top, which assisted with modifications that greatly improved the stability of the robot.

But in addition to using biology to build better robots, Biewener stresses that animal locomotion research is valuable in gaining insights that are relevant to human performance and health. “We make measurements of muscle performance in animals, doing basic science, but then apply it to human performance and improve the accuracy of muscle models used for rehabilitation, for example, like after a person has a stroke.”

As Biewener nears retirement in June 2024, the future of the station remains uncertain. “My absolute key hope is that my department will continue to support the MCZ and the need to hire a new Faculty Director of the lab. That will continue the legacy of the lab and allow for novel, exciting and, I think, valuable comparative physiology and biomechanics research.”

Pygmy goat on the climbing wall outfitted with force plates. Photo by Andrew Biewener