The Meadow Jumping Mouse: A Novel Hibernation Model

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ABSTRACT

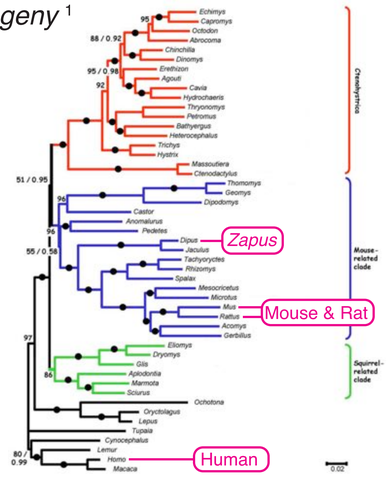
Hibernating mammals exhibit great metabolic flexibility. They transition from a lean summer baseline to a severely obese state in preparation for hibernation. Then, during hibernation in cold climates, they enter a state of metabolic torpor and profound hypothermia and begin a months-long fast. The reversible transition from lean to obese in hibernators may hold lessons for human obesity, and an understanding of how hibernators slow their metabolic rate by >95% may lead to advances in surgery, organ storage, or emergency and battlefield medicine. However, the mechanisms controlling these metabolic changes are not well understood, and past efforts have been limited by shortfalls of existing model organisms. The goal of this research has been to establish the meadow jumping mouse (*Zapus hudsonius*) as a convenient laboratory model of hibernation. Meadow jumping mice are true hibernators; they have a short generation time and can be induced to fatten up and hibernate regardless of outside season. We have established a breeding colony using wild-caught meadow jumping mice and demonstrated control of the hibernation phenotype in the laboratory. Work to sequence the meadow jumping mouse genome is ongoing, and we expect that current experimental efforts will yield new information about the genetic and molecular bases of metabolic regulation during hibernation.

The Meadow Jumping Mouse

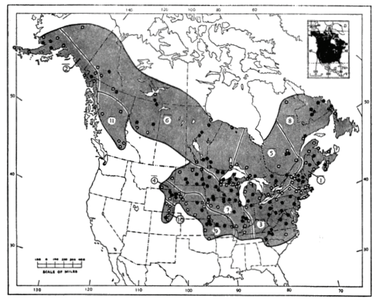
Zapus hudsonius

The meadow jumping mouse is a small hibernating rodent native to North America. *Zapus* are related to laboratory mice (*Mus*), but are evolutionarily more distant from *Mus* than are gerbils and hamsters.

Phylogeny [1]



Range [2]

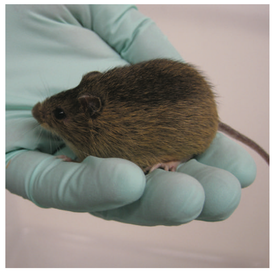


1. Blanga-Kanfi, et al. (2009) BMC Evolutionary Biology, 9(1):71.
2. Krutzsch (1954) University of Kansas Museum of Natural History Publication 7:349-472.

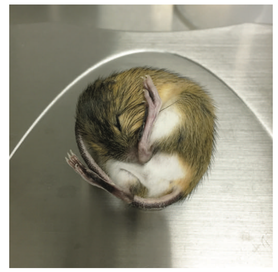
Inducing Hibernation in the Lab

Meadow jumping mice prepare for hibernation based on environmental cues — primarily day length. The mice fatten up and hibernate during simulated fall and winter conditions, but remain reproductively active as long as they are housed in simulated summer conditions.

Lean Mouse
"Summer"



Obese Mouse
"Fall"

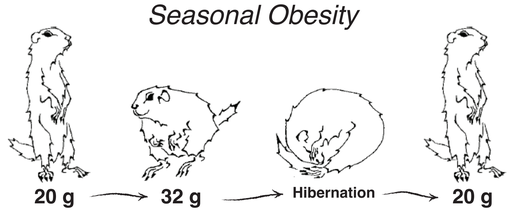


Hibernating Mouse
"Winter"

	"Summer"	"Fall"	"Winter"
Day Length	16 Hours Light	8 Hours Light	Constant Dark
Temperature	24° C	15° C	7° C

Hibernation Physiology

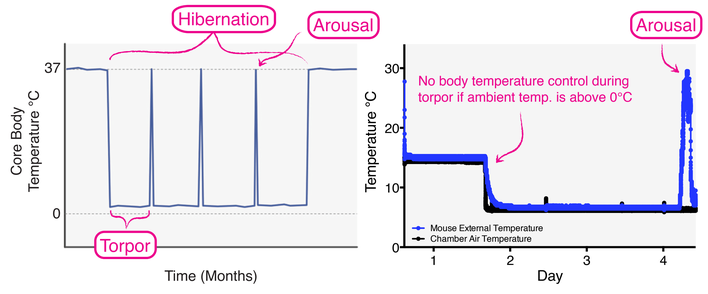
Seasonal Obesity



Hibernators become obese in preparation for hibernation. Their rapid, massive weight gain is accompanied by insulin resistance and other metabolic changes that are seen as unhealthy in humans.

Illustration modified from Boyer & Barnes (1999) Bioscience 49(9):713–724.

Torpor: Severe Hypothermia



The Questions

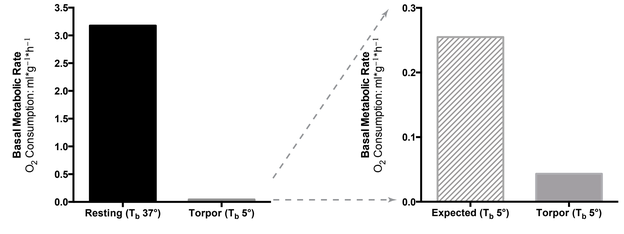
How do hibernators control whole body metabolism?

How is cell metabolism regulated during torpor?

How do hibernators slow metabolism below basal levels?

What is the genetic basis of hibernation phenotypes?

Torpor: Reduced Metabolic Rate



Torpor reduces metabolic rate in *Zapus* by >95%. Much of this energy savings is due to the metabolic slowdown caused by reducing body temperature (T_b); however, the animals actively down-regulate metabolism even further by unknown mechanisms.

Data in the above two graphs calculated from Muchlinski & Rybak (1978) Journal of Mammalogy, 59(2):435–437.
Expected BMR calculated assuming Q_{10} = 2.2.

Establishing the Colony

Because there were no current breeding colonies of meadow jumping mice, we collected wild mice in Massachusetts to found a permanent colony. We have determined the health status of the mice and optimized housing and breeding conditions to suit the natural history of this unique species.

Collecting Mice

Checking a Sherman trap in the field

Housing & Breeding

Two-chambered nest box

Large breeding cage with two next boxes

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