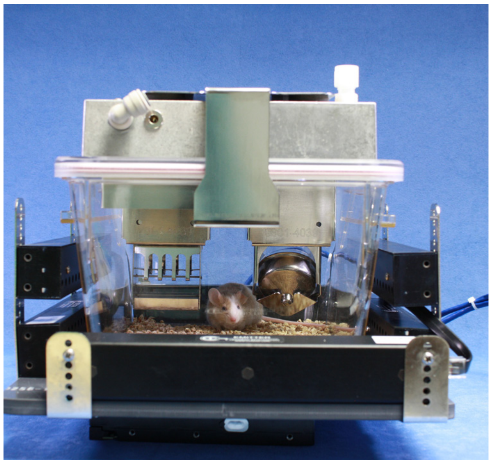
Comprehensive Lab Animal Monitoring System

# CLAMS

CLAMS has been the industry leading metabolic monitor since 1999, and our vast and distinguished customer base helps drive improvements and innovations which places the system at the forefront of metabolic and behavioral research. Each system is built on a semi-custom basis to include as many, or as few options that are needed to meet the experiment needs or budget. Customers not only choose the parameters to be measured, but also a variety of cage environments to cover all potential applications. No matter the challenge, we have something that will work.

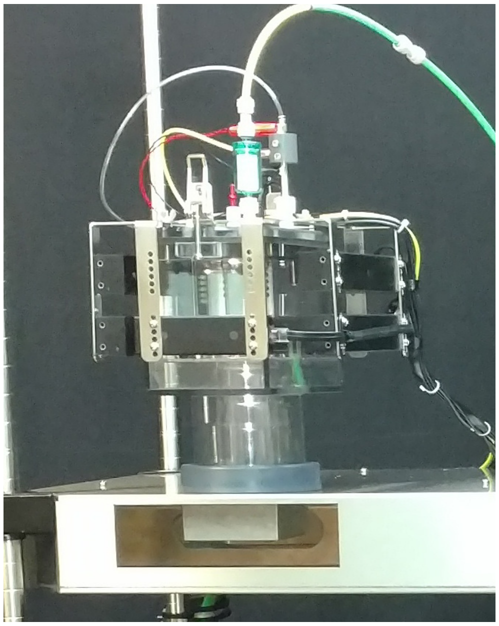
## CLAMS-HC
## for home cages:

Our most popular offering, the cage most closely resembles the normal IVC cage, which lowers stress and facilitates acclimation. The cage and cage parts are cage-washer safe, making for a real “work horse” that is robust, reliable, and easy to use on a daily basis.



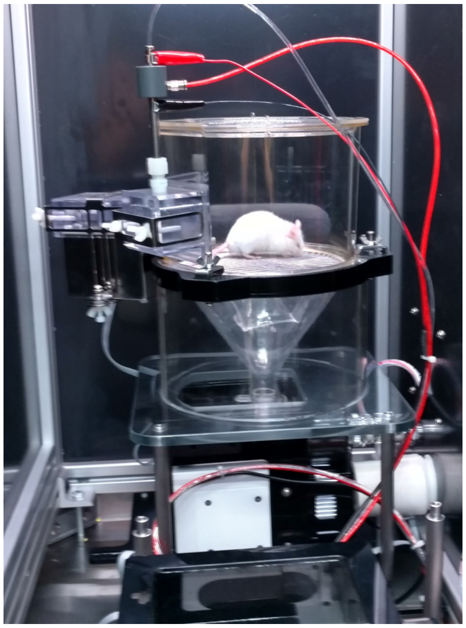
## CLAMS
## Center-feeder

An ideal cage design for obese models or for experiments that require the highest possible certainty for food intake measurements. Powdered food is presented from the floor, a large spill cup catches spillage, and the feeder is designed to eliminate food caching and foraging.



## CLAMS-WC
## for waste cages

Urine and feces collection require a novel and uniquely shaped cage, with a funnel beneath a wire floor that allows waste material to fall through for collection. We have mechanically adapted many of our CLAMS sensors to fit on these “metabolic” cages.



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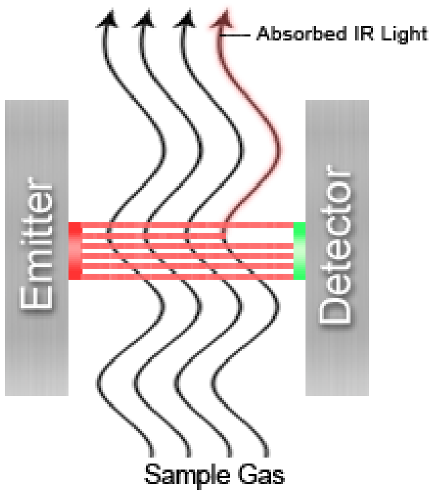
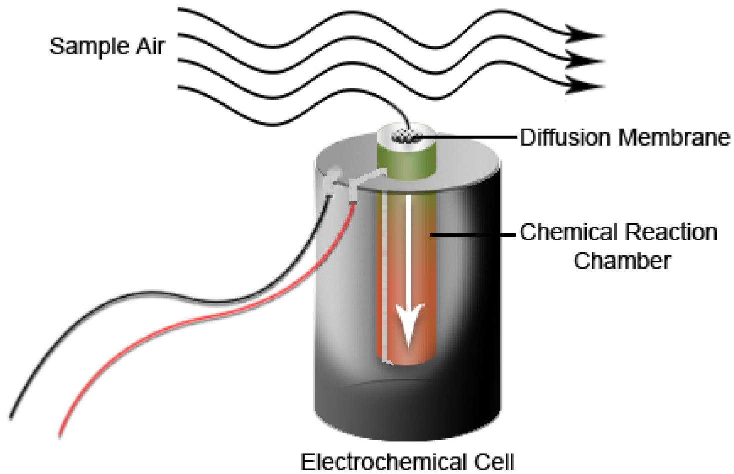
# Calorimetry (Oxymax)

In general terms, measuring the exchange of carbon dioxide for oxygen is known as indirect calorimetry. The ratio of the exchange varies depending on if the animal is metabolizing fat, carbohydrate, protein, or a mixture of the three. This exchange can be monitored by placing the subject inside a sealed cage and precisely throttling the air-flow to create small differentials of oxygen and carbon dioxide between fresh air in vs. sample-out of the cage. A variety of gas sensing technologies exist for measuring these differentials. As our systems are highly customizable and flexible, we offer a variety of sensors that each have their own ideal application.



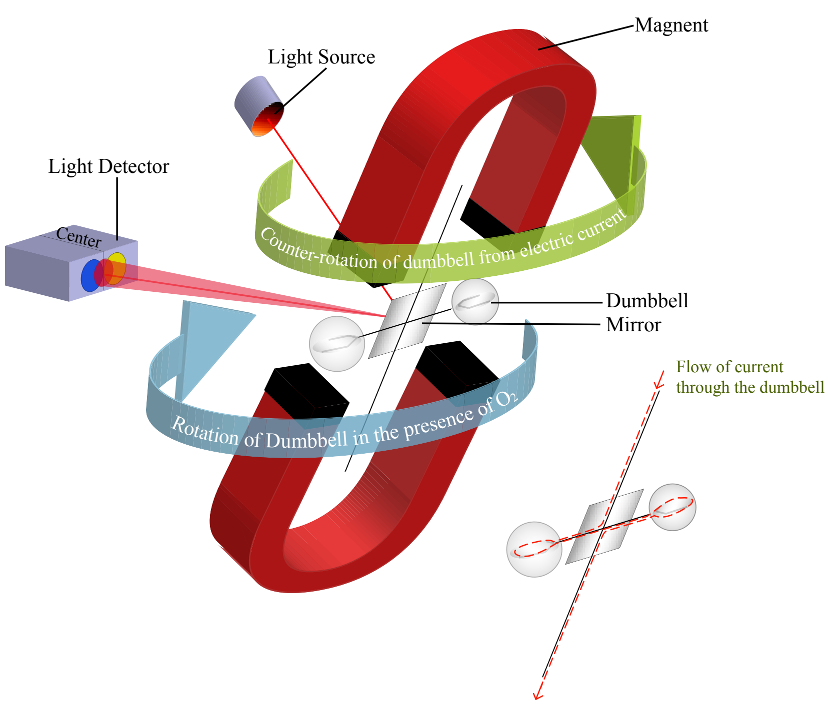




## Carbon Dioxide sensing via NDIR:

Carbon dioxide gas absorbs IR light at a very specific wavelength. The sample air is passed through the sensor, an IR emitter emits a known amount of IR light and the amount absorbed by the sample is recorded by the detector.

## Oxygen sensing via Electrochemical sensor:

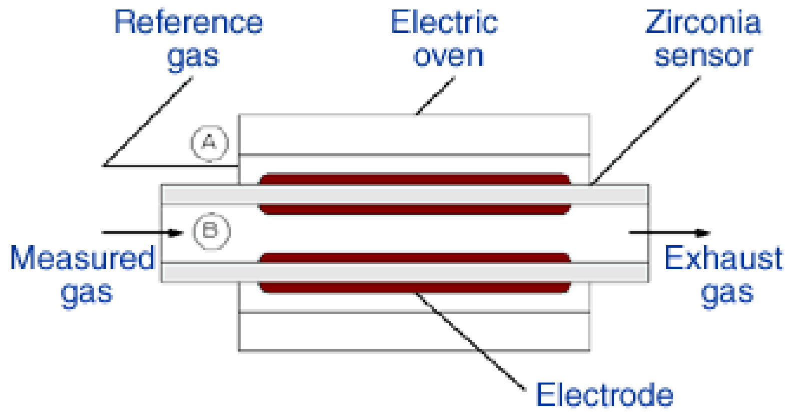
The electrochemical "fuel cell" sensor is a battery. A special membrane allows oxygen from the sample air to enter the fuel cell and this oxygen drives the chemical reaction that produces a voltage proportional to the amount of oxygen. It's highly accurate at a low cost. However, it requires periodic replacement and the sensor is slow when multiplexed. Best for small systems or for continuous-sampling systems.




## Oxygen sensing via Paramagnetic sensor:

The paramagnetic sensor exploits the paramagnetic properties of O2 by suspending a specially designed dumbbell within a magnetic field. As the dumbbell is exposed to O2, the dumbbell twists. By applying a current through the dumbbell, the twist can be counter-rotated. A light detector bounces a light off a mirror attached to the dumbbell and 2 light sensors detect when the dumbbell is centered. The amount of current needed to untwist the dumbbell is proportional to the concentration of O2. The sensor is amazingly accurate and stable, but it's large sensor volume means it's slow when multiplexed. Despite this limitation, it is durable and maintenance free, which is why we include it standard with all Oxymax-equipped CLAMS systems. Ideal for small to medium systems (8 stations and under).

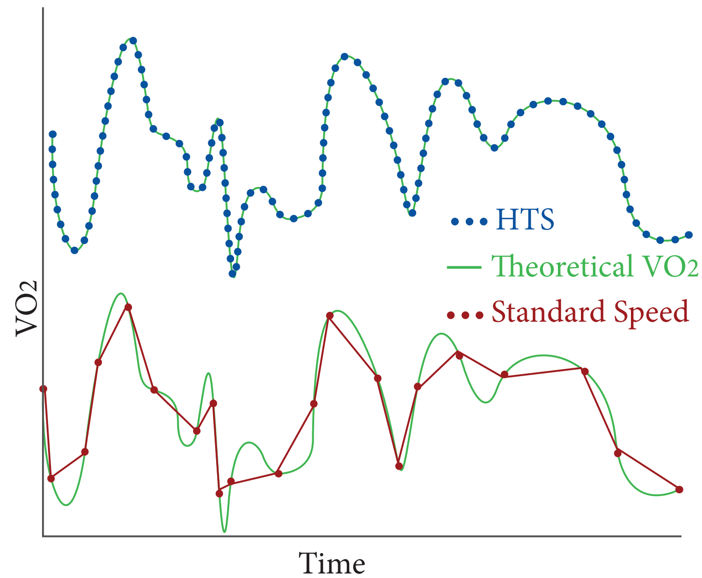
## Oxygen sensing via Zirconia sensor:




The “High Speed” Zirconia differential sensor works by heating Zirconium Dioxide to very high temperatures. Ambient air and sample air are introduced on either side of the Zirconium Dioxide where it then conducts electricity as oxygen ions passes through, creating a Nernst voltage. This voltage is proportional to the difference between fresh air and sample air. While the sensor is very expensive, it is also very fast, ideally suited to multiplexed systems with a large number of cages.

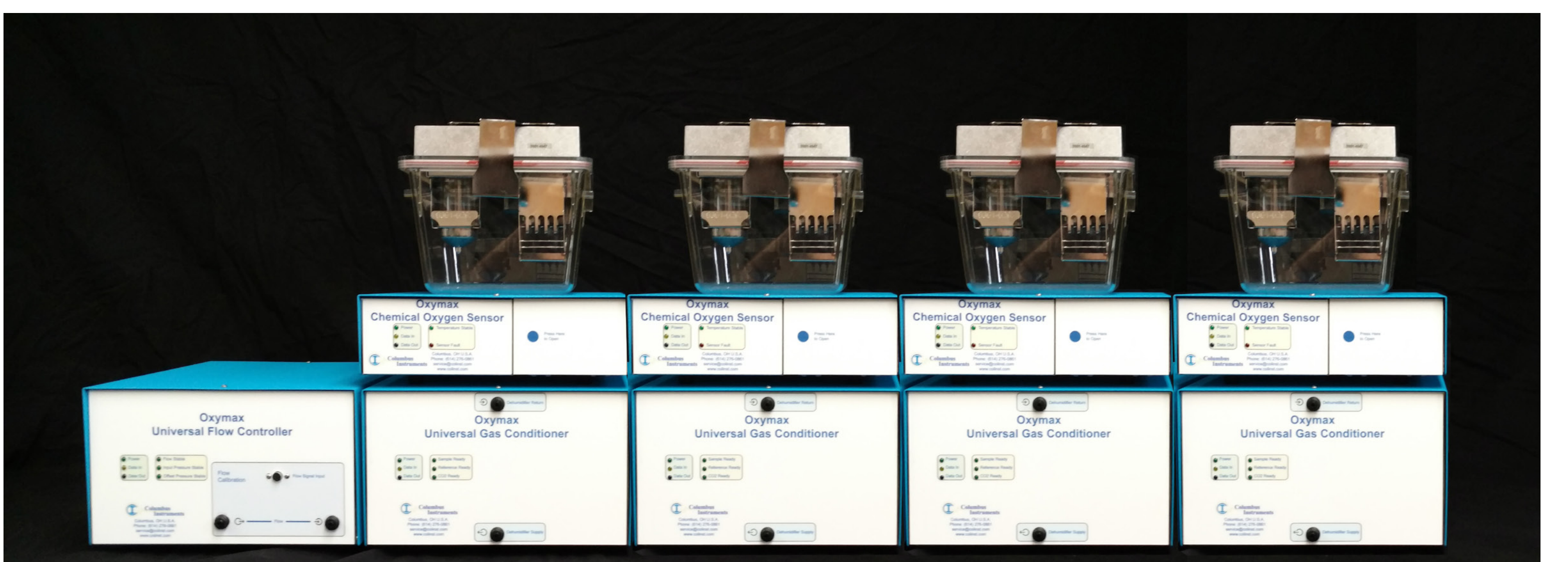
## High Throughput Scanning (HTS):

A new feature of our multiplexed Zirconia equipped Oxymax systems is the High Throughput Scanning mode. With an increased air flow and industry leading sensor resolution, these systems are capable of scanning each cage 6X faster than our standard sensors! This means 6X more data points for any given experiment, which yields much more detailed data.



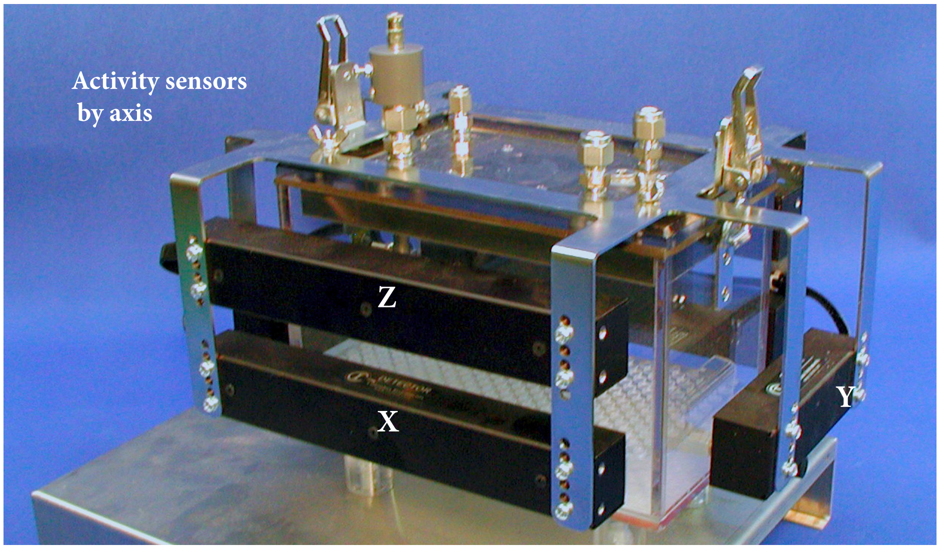

## Oxymax F.A.S.T. Continuous Sampling

Starving for even more data points? Our Frequent Assessment Sensor Technology Oxymax is a continuous-sampling calorimeter that eliminates the sensor settle time that is necessary each time the system switches to the next cage in multiplexed systems. Every subject gets their own dedicated electrochemical oxygen sensor and NDIR carbon dioxide sensor for true simultaneous measurements. While these systems are most commonly employed with our metabolic treadmills for $VO_2$ max studies, the Oxymax F.A.S.T. can also be equipped to our CLAMS-HC or CLAMS-CF systems.




**Oxymax F.A.S.T. for 4 mice.**

# Activity




Animal activity is recorded with an array of infrared photo beams that surround the cage. As the animal moves, the beams are interrupted. Rapid breaks of the same beam over and over indicate fine repetitive movements like grooming. And since the beams are arranged in a grid pattern, the XY position of the animal can be continuously recorded. When equipped with the Z axis sensor, rearing events can be detected. Photo beam activity monitoring has been a staple of behavioral monitoring for decades, and we provide a few different activity data files to help digest the rich data.

## .CDTA

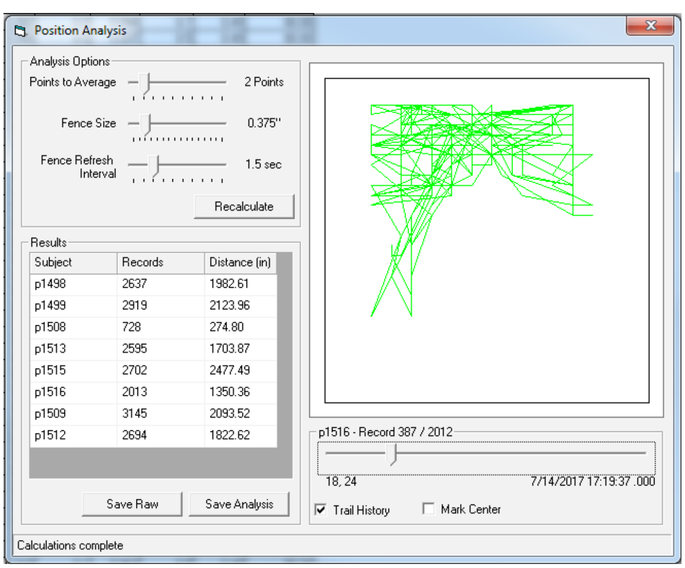
More commonly known as the calorimetry data file, it also contains the synchronized beam break counts binned together in the same interval as the calorimeter readings. Beam breaks are categorized as locomotor beam breaks or total beam breaks (locomotor + repetitive beam breaks).

## .ADTA

This contains the high resolution data with shorter intervals (user adjustable).

## .PDTA

The true behavioral data file, distance traveled and the XY coordinates are streamed to a dedicated file. The software has a “VCR” replay of the path of movement for a selected area of data.




| | | | | | | |
|---|---|---|---|---|---|---|
| 10 | SAMPLE FREQ:10 seconds | | | | | |
| 14 | ========= | ============= | ============== | ====== | ======= | ====== |
| 15 | INTERVAL | GROUP/CAGE | DATE/TIME | XTOT | XAMB | ZTOT |
| 17 | ========= | ============= | ============== | ====== | ======= | ====== |
| 18 | 1 | 104 | 2/7/2008 14:31 | 7 | 2 | 0 |
| 19 | 1 | 104 | 2/7/2008 14:31 | 10 | 0 | 0 |
| 20 | 1 | 104 | 2/7/2008 14:31 | 13 | 9 | 0 |
| 21 | 1 | 104 | 2/7/2008 14:31 | 8 | 1 | 0 |
| 22 | 1 | 104 | 2/7/2008 14:31 | 9 | 1 | 0 |
| 23 | 1 | 104 | 2/7/2008 14:32 | 8 | 2 | 0 |
| 24 | 1 | 104 | 2/7/2008 14:32 | 10 | 1 | 0 |
| 25 | 1 | 104 | 2/7/2008 14:32 | 47 | 35 | 8 |
| 26 | 1 | 104 | 2/7/2008 14:32 | 14 | 6 | 5 |
| 27 | 1 | 104 | 2/7/2008 14:32 | 59 | 42 | 6 |
| 28 | 1 | 104 | 2/7/2008 14:32 | 39 | 29 | 6 |
| 29 | 1 | 104 | 2/7/2008 14:33 | 8 | 5 | 10 |

.ADTA data file sample

## Sleep Analysis

Bouts of *inactivity* of a certain duration are scored in an event file as sleeping events. As validated with simultaneous recordings of EEG and photocell based activity monitoring, extended periods of motionlessness have a very high correlation with sleep.

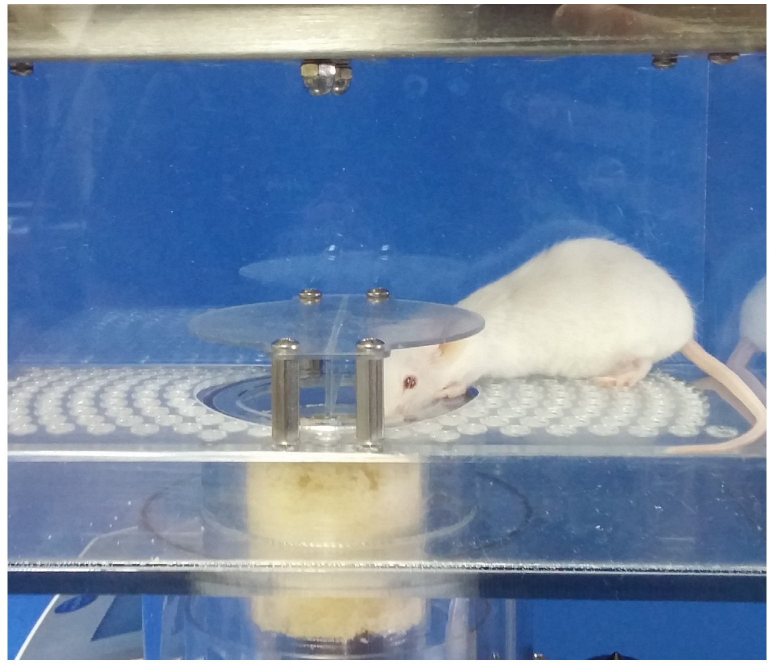

* Novel method for high-throughput phenotyping of sleep in mice
**Allan I. Pack, Raymond J. Galante, Greg Maislin, Jacqueline Cater, Dimitris Metaxas, Shan Lu, Lin Zhang, Randy Von Smith, Timothy Kay, Jie Lian, Karen Svenson and Luanne L. Peters**
Physiological Genomics 28:232-238 (2007)

# Food Intake

One of the largest differences between cage types is the presentation of food. This can have a large impact on the feeding behavior and the amount of food eaten during the experiment. Each has it's pros and cons, but some exist for very specific experiment conditions. Data is recorded in both a high resolution file and the event driven .BDTA bout file.

## CLAMS-HC

The overhead feeder is designed to place the food in a familiar location and in pellet form, just like the IVC cage. A spillage catch beneath the pellets catches crumbs so the weight is accounted for. The animal has access to eat the crumbs as well, which can lead to minor spillage.

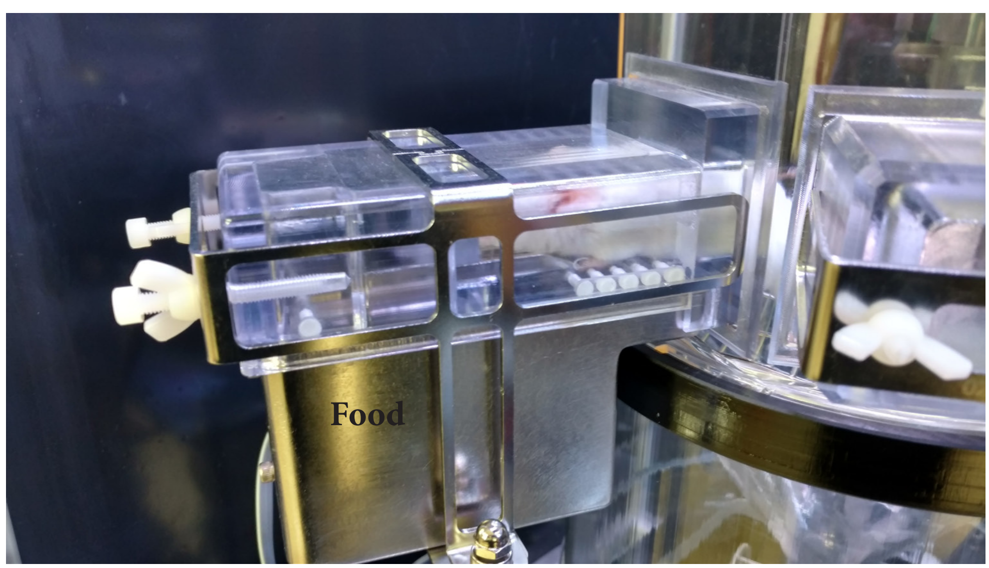


## CLAMS-CF

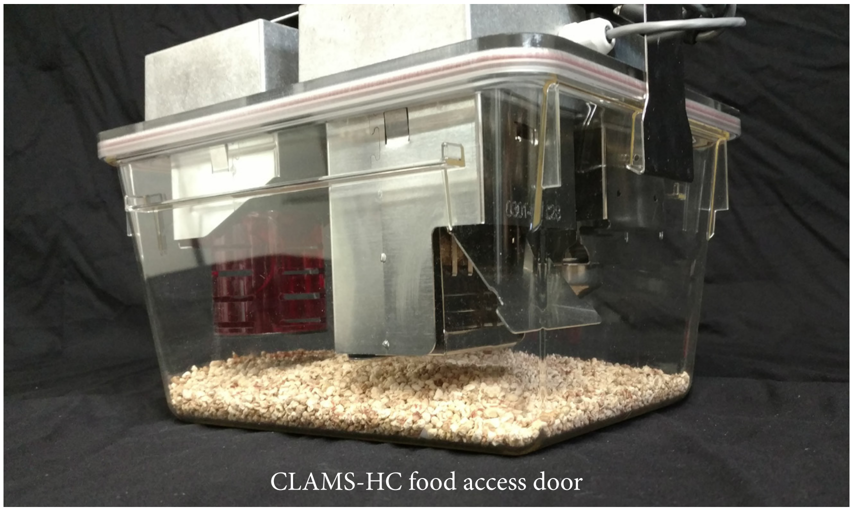
The center feeder presents powdered food from the floor. Originally designed for Ob/Ob mice that could not lift their head to eat, the cage became wildly popular and the feeder was capable of easy modification for all mouse types. The combination of powdered chow and the restricted access to spilled food makes this an incredibly accurate food intake system, albeit after sufficient acclimation.

## CLAMS-WC

The most restrictive feeder of the group, and purposefully so. Keeping food crumbs off the urine funnel is of the highest importance in this feeder design. The animal must crawl through a tunnel to access powdered food from a dish. Special ribs in the tunnel fluff the belly fur upon exit to remove any crumbs. The length of the tunnel is also carefully designed to have the maximum length to prevent crumbs, but not so long that the animal can urinate in it.



# Automated Food Access



CLAMS-HC food access door

This option allows the researcher to program when the subjects will have access to food. Access to the food source is controlled by a servomotor-powered door and can be programmed based on time, mass, time & mass, "energy value," or yoked & pair feeding.

Balance Management

| Feeder | Cage | Combine | Energy/g |
|---|---|---|---|
| 010101 | 1 | ☑ | 100 |
| 010102 | 1 | ☑ | 400 |

"Energy value" restriction requires assigning an energy value per gram of food in each cage.

Balance Management

| Feeder | Cage | Group # | Master | Multiplier |
|---|---|---|---|---|
| 010101 | 1 | 1 | ☑ | 1 |
| 010201 | 2 | 1 | ☑ | 1 |
| 010301 | 3 | 1 | ☐ | 1 |
| 010401 | 4 | 1 | ☐ | 1 |
| 010501 | 5 | 2 | ☑ | 1 |
| 010601 | 6 | 2 | ☑ | 1 |
| 010701 | 7 | 2 | ☐ | 1 |
| 010801 | 8 | 2 | ☐ | 1 |
| 010901 | 9 | 3 | ☑ | 1 |

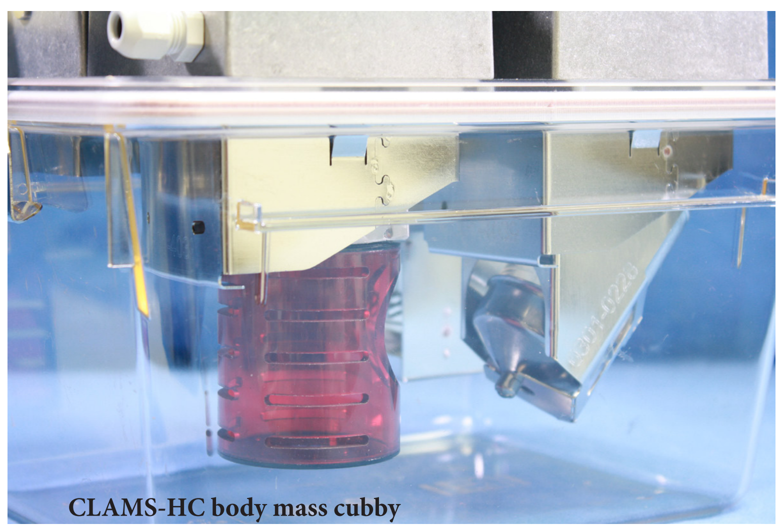
Pair feeding menu showing selection of master cages.

# Body Mass

## CLAMS-HC and CLAMS-CF

Body mass of the subjects can be periodically weighed by suspending a red translucent enrichment cubby from a precision load cell. While entry into the cubby is strictly voluntary, most subjects will sleep in it. This option is not available for the CLAMS-WC system.

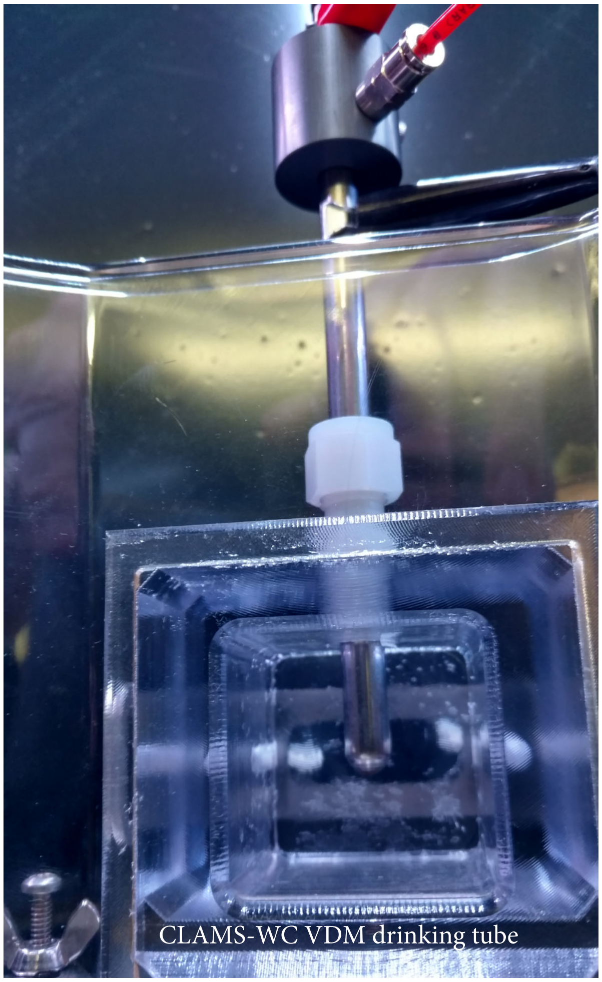
The body mass monitor in CLAMS-HC has some additional flexibility. The cubby, feeders, and drinkers have a universal clip that attaches them to the load cells. These elements can be rearranged and combined in different ways for specific experiments. Most commonly, the body mass cubby can be replaced with a second feeder or drinker for diet or drink preference studies.



**CLAMS-HC body mass cubby**

# Drinking

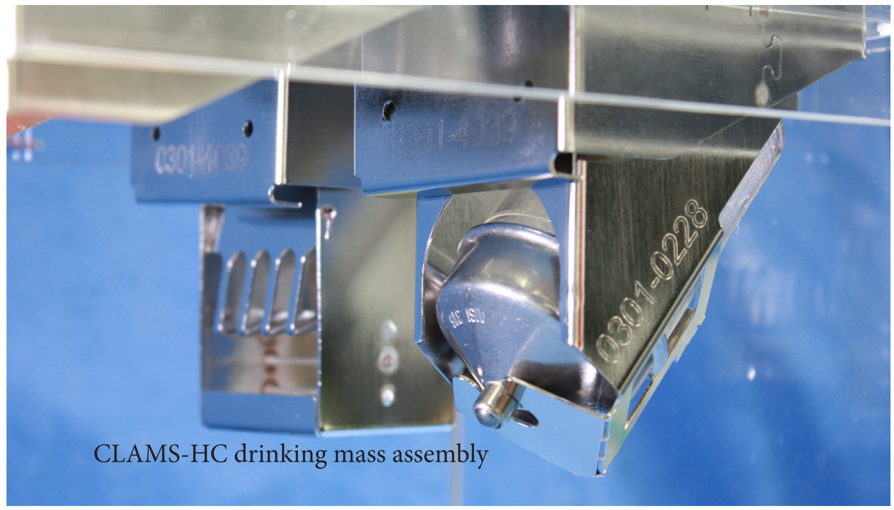
Drinking can be monitored either by mass or with our patented Volumetric Drinking Monitor. Similar to the food intake data, drinking data is reported synchronously with the calorimetry data file. But also a high resolution drinking file and events recorded in the .BDTA bout file.



CLAMS-WC VDM drinking tube

## CLAMS-CF and CLAMS-WC

Our patented Volumetric Drinking Monitor (VDM) uses a small dosing pump to deliver water through, what look like, a standard sipper tube. Inside the sipper, however, is a water level detection circuit that signals the pump for more water when the animal drinks.




CLAMS-HC drinking mass assembly

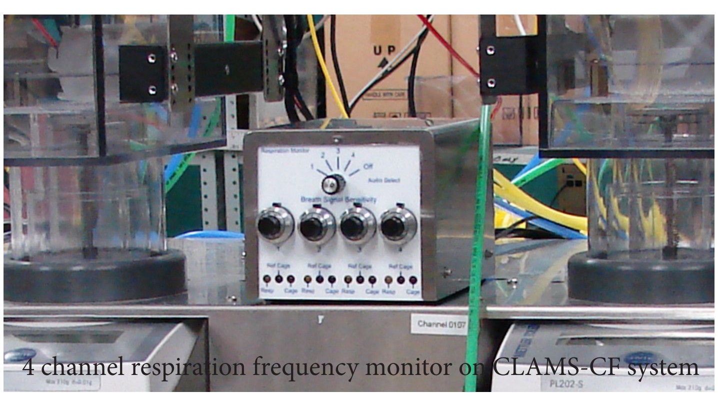
## CLAMS-HC

A water bottle is suspended from a precision load cell and the weight of the bottle is constantly monitored. Access to water can also be controlled in a similar fashion as the automated food access option.

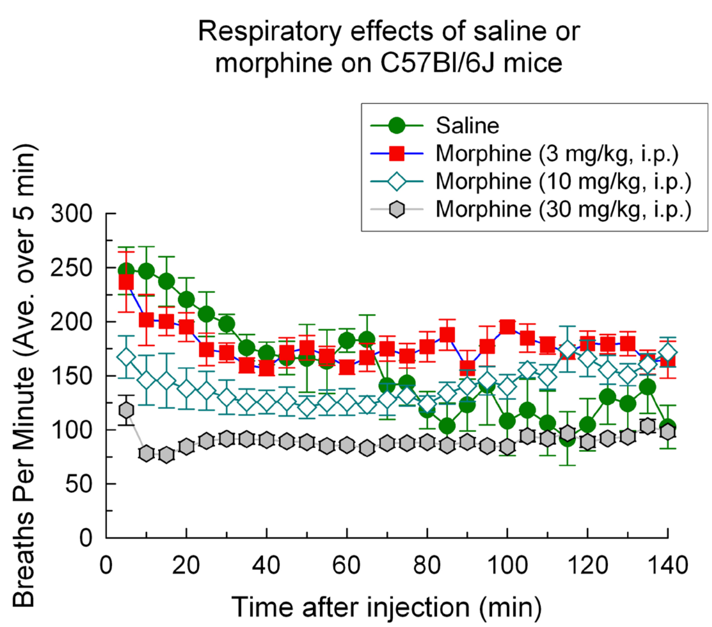
# Respiration Frequency

## CLAMS-HC and CLAMS-CF

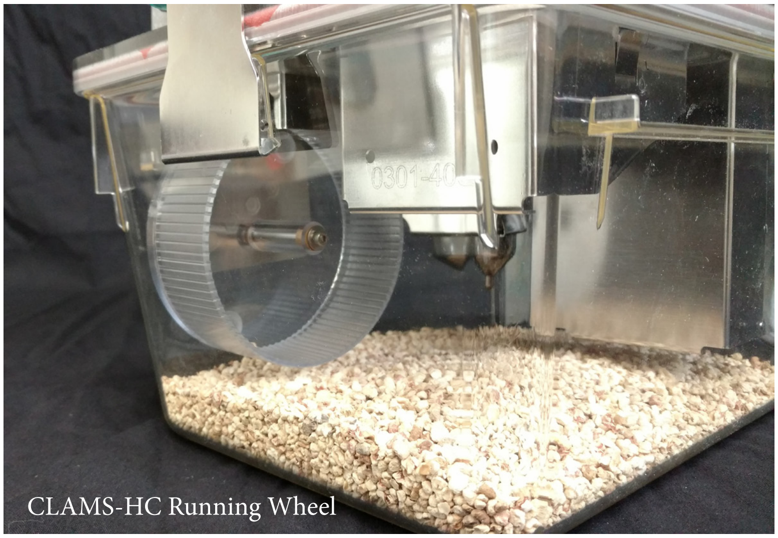
Respiration frequency can be measured by monitoring small pressure fluctuations within the chamber that result from the subject inhaling and exhaling.



4 channel respiration frequency monitor on CLAMS-CF system



# Wheel Running

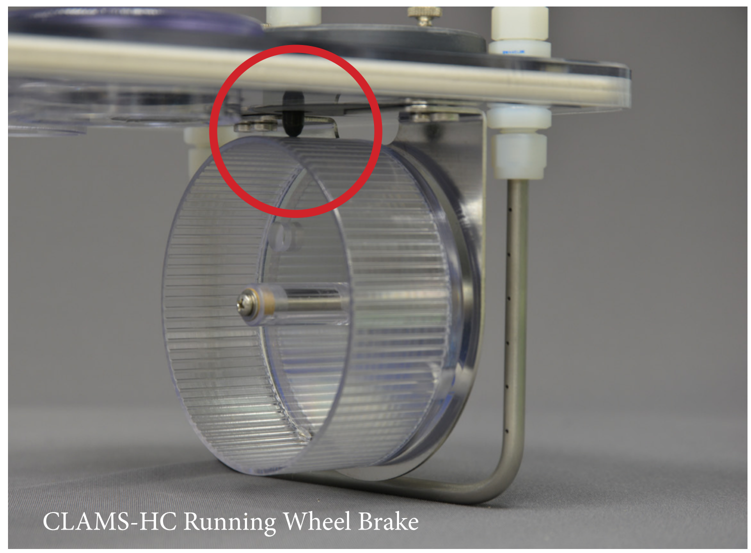


CLAMS-HC Running Wheel

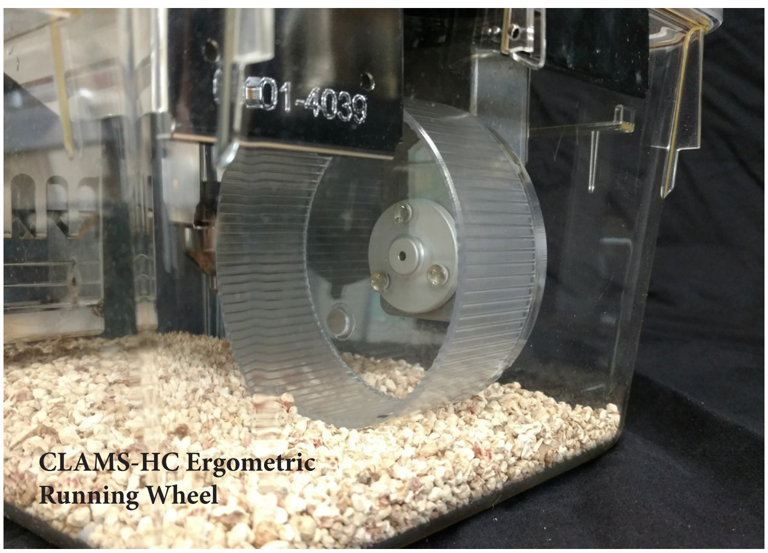
The free spinning running wheel records the number of revolutions which reports the counts in bins. The .CDTA file syncs rotations with calorimetry data, while a high resolution running file breaks out the counts into shorter intervals. Bursts of spontaneous exercise activity are recorded in the .BDTA bouting file. The running wheel is available for CLAMS-HC and CLAMS-CF, but it sadly does not fit in the CLAMS-WC cage.

## Running Wheel Brake

A servomotor can activate a wheel chock that prevents the wheel from spinning at specific intervals or under certain conditions.



CLAMS-HC Running Wheel Brake

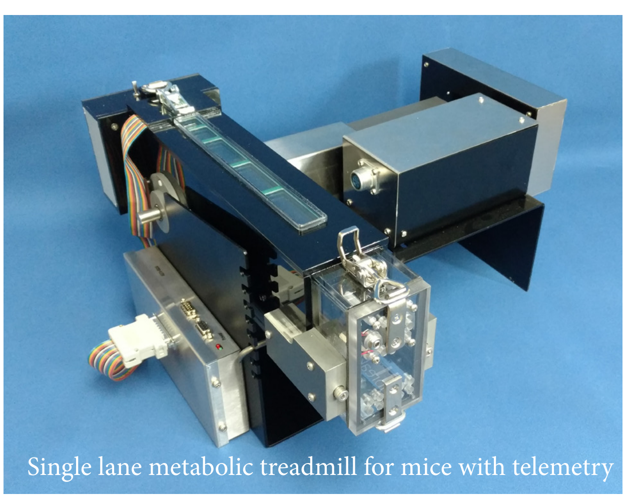


**CLAMS-HC Ergometric Running Wheel**

## Ergometric Running Wheel

The running wheel can also be equipped with a magnetic brake that applies a precise resistance on the wheel. In practice, the wheel free-spins until it is up to speed, then the resistance subtly increases. With a known resistance, and distance, it allows the calculation of Work.

# Metabolic Treadmill



Single lane metabolic treadmill for mice with telemetry

VO2max measurements are made possible with a treadmill within an airtight chamber. Our Modular Metabolic Treadmill can be configured from 1 to 32 lanes. Available options include shock, shock with counter and limiter, motorized incline, and telemetry.

All speed and angle changes can be programmed from the calorimeter experiment setup menu. When equipped with all options, the system collects $VO_2$, $VCO_2$, RER and Energy Expenditure, treadmill speed, individual distance run, amount of shock administered, core body temperature and heart rate.

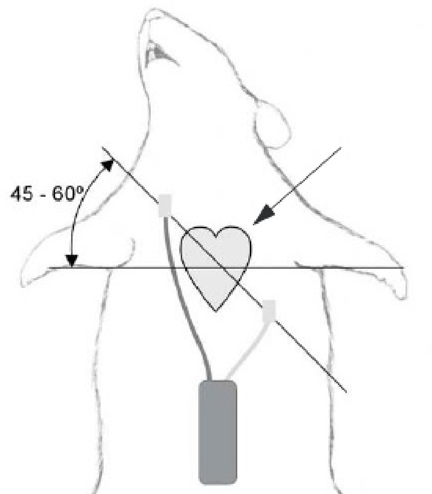
# Telemetry

Wireless measurements of core body temperature and heart rate are made possible by using radio telemetry. The calorimetry synced data is available in the .CDTA file, but also high resolution readings at shorter intervals are recorded in a dedicated file.

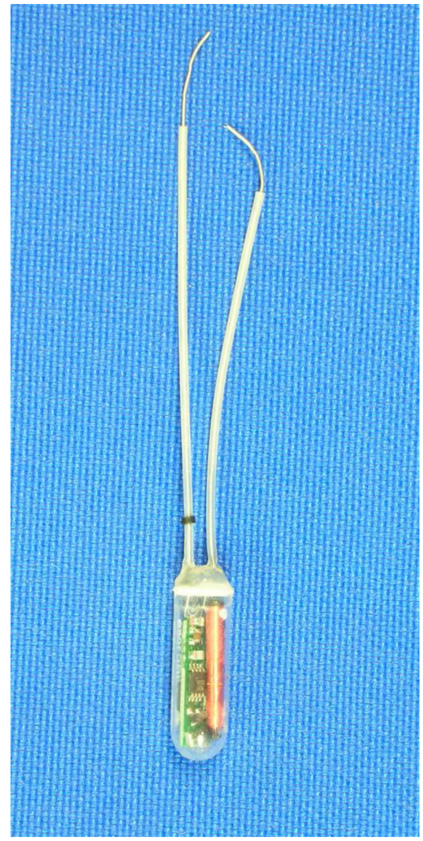
Our transmitters are powered inductively through the antenna that surrounds the cage. With no battery on board, the transmitters are smaller than traditional transmitters. And with no battery to service, they last longer too.

Telemetry is available in the CLAMS-HC and CLAMS-CF systems. Unfortunately it cannot be implemented on the CLAMS-WC.

Temperature Transmitter
15.5 x 6.5 mm , 1.1 grams




Heart rate lead placement



Temperature & Heart Rate Transmitter
26 x 6.5mm , 1.5 grams

# Temperature and Light Control Enclosure

Ambient temperature has an enormous impact on metabolic activity. Our environmental enclosures give the researchers precise control over the temperature and the light/dark cycle. The temperature is programmable between 5° to 32°C and includes an internal air circulation system for maintaining temperature uniformity, especially at cold temperatures.

Light is provided by LED strips with programmable timing, intensity, and even color. An advanced menu in the experiment setup allows for very intricate changes in temperature or light patterns.

24 Station CLAMS-CF
with two 12-station enclosures

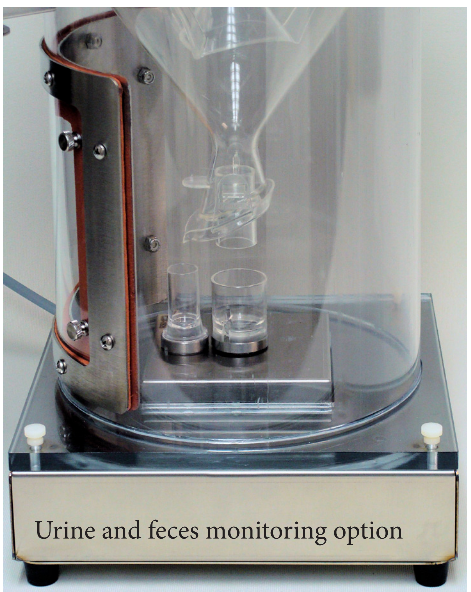
# Waste Monitoring


4 Station CLAMS-WC system for Mice

## CLAMS-WC

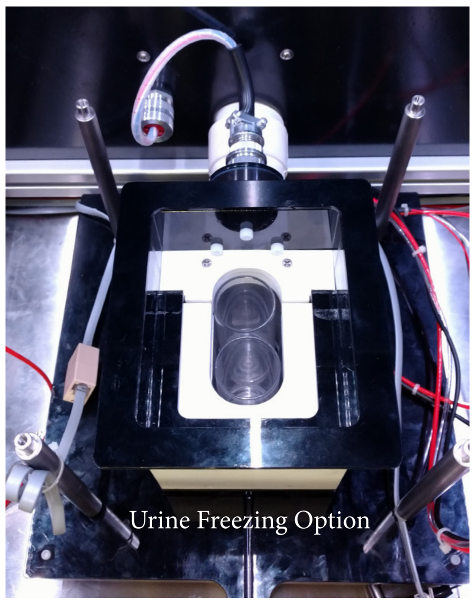
The waste collection cages are designed to maximize living space while minimizing the surface area of the funnel beneath the floor. Keeping the funnel surface area small ensures higher collection yield and more accurate measurements. A separator at the bottom allows collection of urine and feces in separate vials. Those vials can be placed atop precision load cells for automated scoring for weight and time-stamped voiding events in the .BDTA bouting file.

## Automatic Voiding Detection


Urine and feces monitoring option

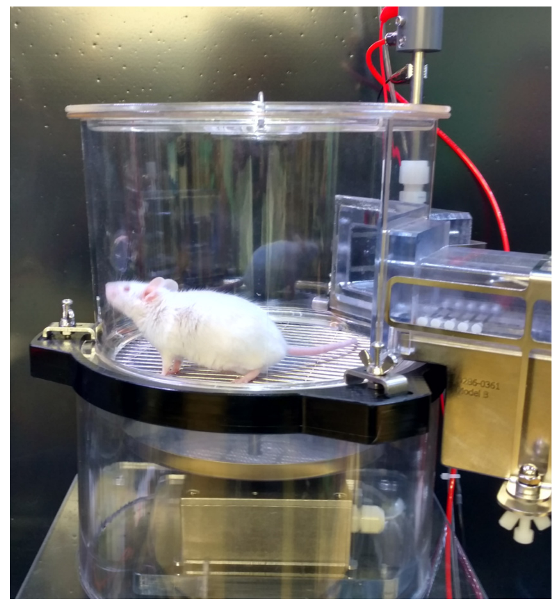
Urine and feces are separated and collected in sample vials. The vials rest upon load cells which continuously monitor the weight. When the weight increases, it is time stamped and quantified in the bouting file.

## Urine Freezing


Urine Freezing Option

A powerful thermoelectric cooler preserves samples for later analysis. The cooler features a 2 piece cooler assembly that is held together with a magnetic latching system, which allows for easy access to the sample vials.

## UroFlow

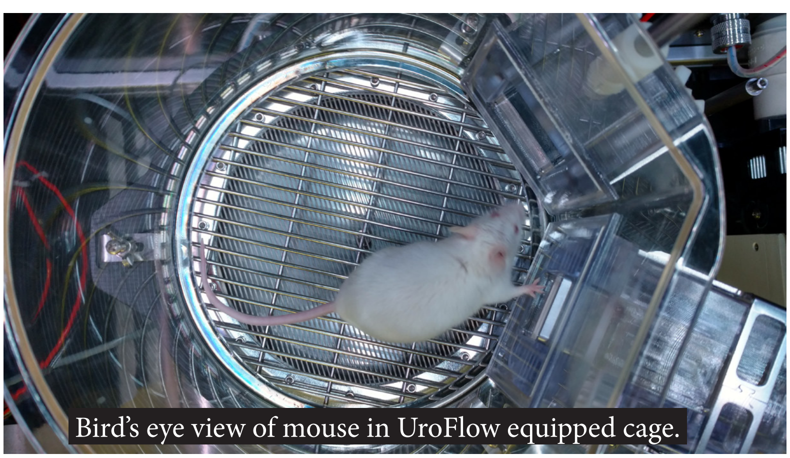


A special adaptation to the stock urine CLAMS-WC cage, the funnel assembly is replaced with a load cell and urine plate. When the subject urinates it free falls onto the plate. Data from the load cell is streamed into a dedicated file to reconstruct the flow of urine.

**Mouse cage dimensions:**

Livable area: 7 inches (17.75 cm) diameter, 5.625 inches (14.25 cm) ceiling height.

Overall size with base and stand: 15 inches (38 cm) W, 11 inches (28 cm) D, 23 inches (58.4 cm) H.


Bird's eye view of mouse in UroFlow equipped cage.

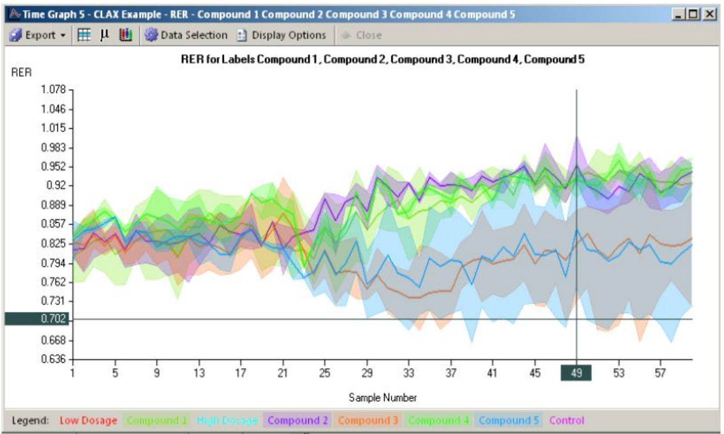
**Rat cage dimensions:**

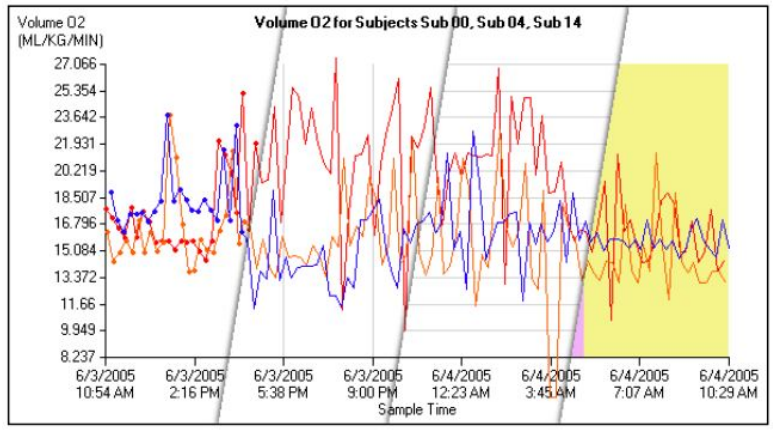
Livable area: 8 inches (20.3 cm) diameter, 5.125 inches (13 cm) ceiling height.

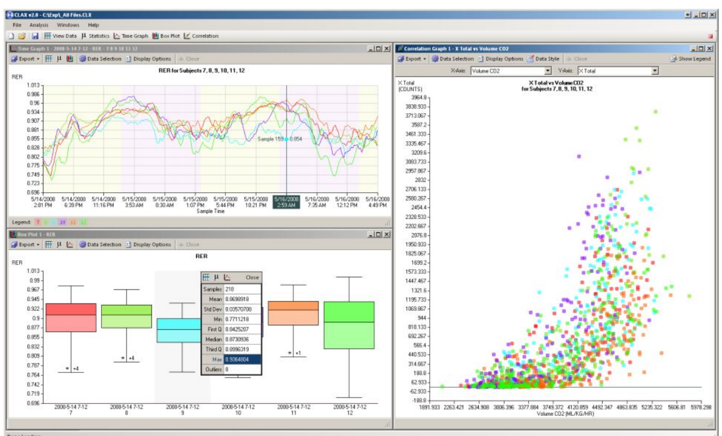
Overall size with base and stand: 16 inches (40.6 cm) W, 11 inches (28 cm) D, 23 inches (68.6 cm) H.

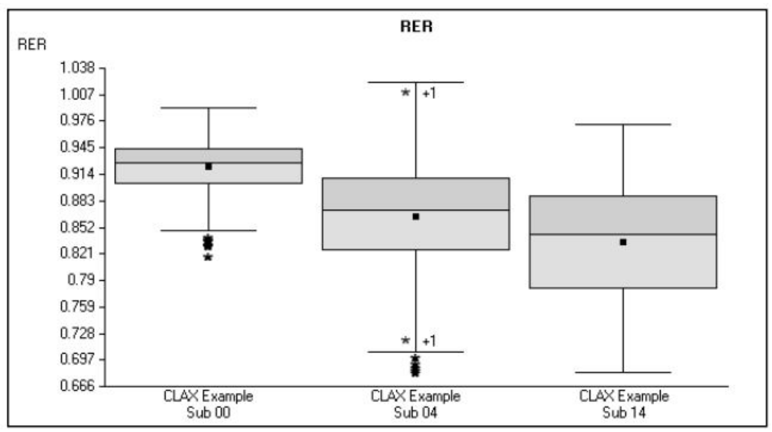
Every CLAMS measurement can be viewed and exported in a delimited format for use in other programs. Tabular data may be saved in TXT (tab or Semicolon separated) or CSV (comma separated value) formats. Graphs generated by CLAX can be printed or saved in a variety of standard image file formats: BMP, GIF & PNG. These may be easily imported by other program for preparing presentations.

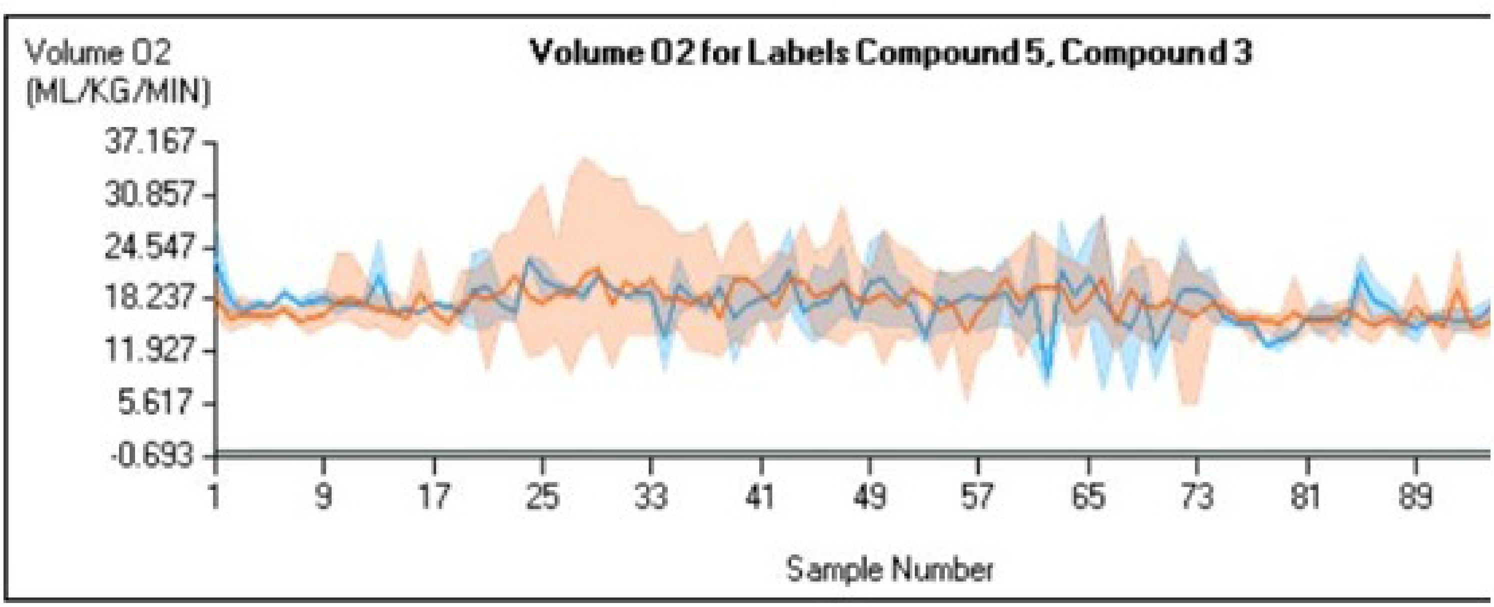
CLAX is also license free, collaborators are welcome to install it so that they can examine and export data from the native raw data files. The program also includes some basic statistical functions designed for quick screening and comparing of multiple data sets.



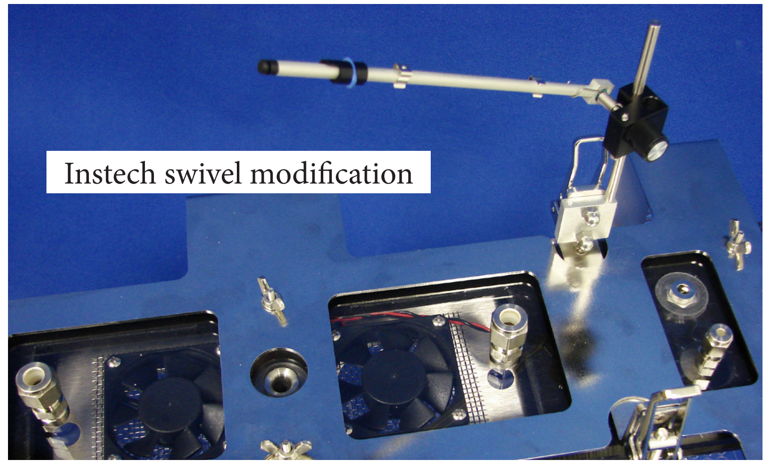


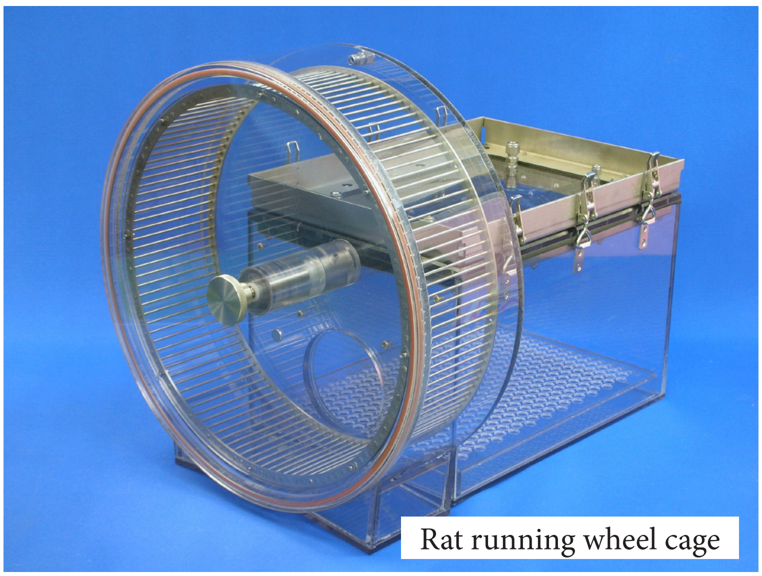



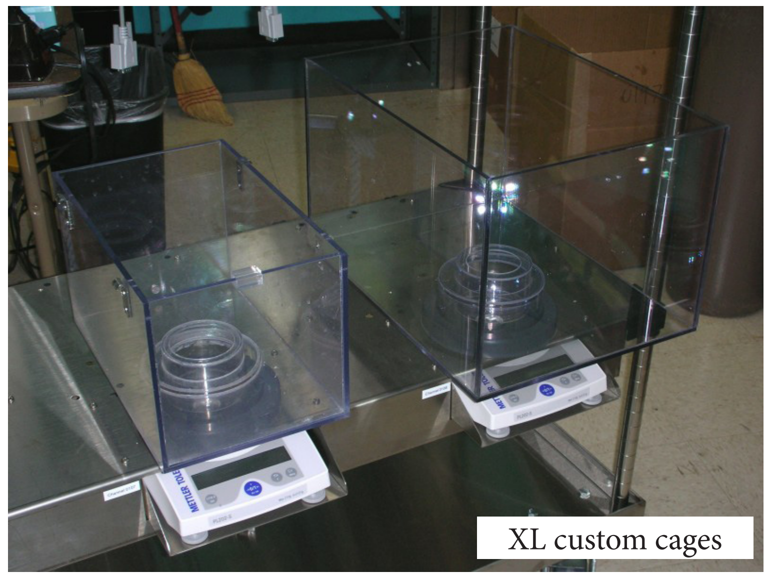
# One-offs

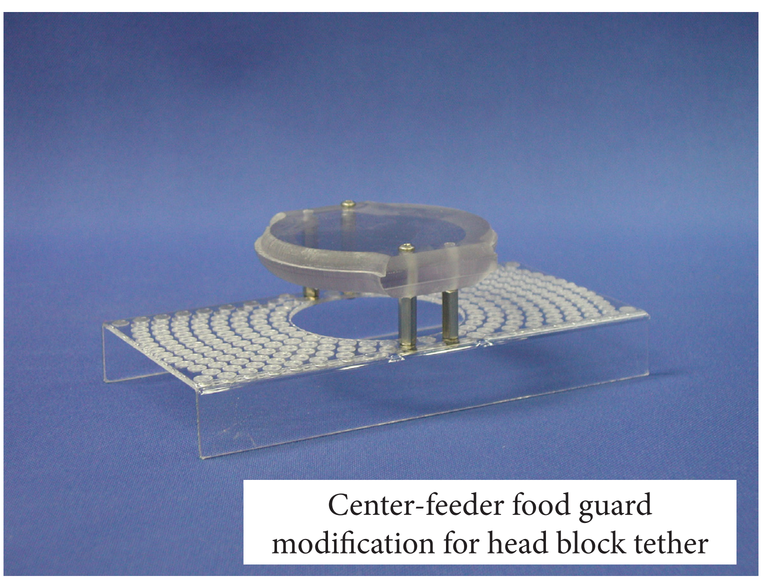
We pride ourselves on flexibility and have made a great number of one-off modifications for special applications. Here are a few examples:

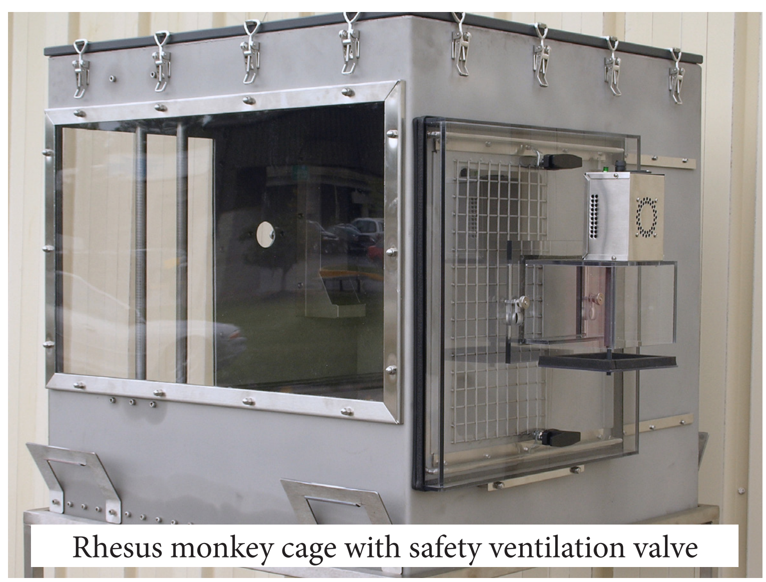

Double feeder for diet preference


Instech swivel modification


Rat running wheel cage


XL custom cages


Center-feeder food guard modification for head block tether


Rhesus monkey cage with safety ventilation valve

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