Laboratory Equipment®
DISCOVERY & DESIGN IN THE LAB

Safe and Effective Research in the Vivarium

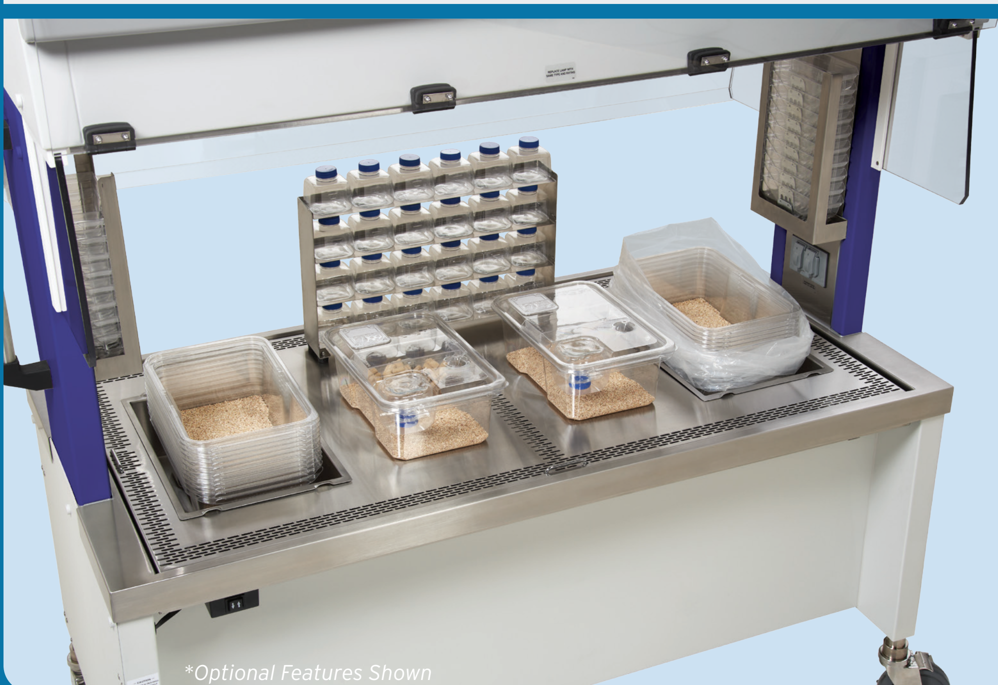
SPONSORED BY
NuAire

Contents

MAXIMIZE Mobility & Versatility

ALLERGARD ES + innovive

NU-S620 INNOVIVE® EDITION ANIMAL TRANSFER STATION



*Optional Features Shown

- Provides ISO Class 4 Air Sterility
- Open & Stack Feeders in Side Holders
- Built-In Deep Wells for Mouse/Rat Cages
- Fold-Out Side Shelf for Stacking
- Extra-Large Access Opening

The **NuAire AllerGard™ NU-S620 Series Innovive® Edition Animal Transfer Station** are specifically designed to work with **Innovive® Disposable IVC Caging System** for mice and rats to maximize efficiency and versatility.

NUAIRE

Request a Quote Online at www.nuaire.com or Call (763) 553-1270

NuAire, Inc. | 2100 Fernbrook Lane | Plymouth, MN 55447 | U.S.A. | www.nuaire.com

Protecting Animals and Vivarium Workers in a Rodent Facility

by Marco Breuer

A room inside the Animal Facility of the Netherlands Institute of Neuroscience.

Working in a modern rodent animal laboratory facility raises several challenges regarding the health and safety of animal care staff and researchers, as well as the animals they work with. The most prominent risk to animal care staff and researchers is developing a laboratory animal allergy (LAA). Previous studies have shown between 10-45% of the people working in a lab animal environment will develop a mouse or rat allergy. Symptoms are mostly mild, like sneezing, watering and itching eyes. However, some will develop more severe symptoms, which can affect their ability to operate within a lab animal facility, endangering their health and livelihood. Although lab animal allergies are probably the most eye-catching risk, animal care staff and researchers can also be exposed to other hazardous materials like gas anesthetics and toxic substances used in experiments like carcinogenic, mutagenic, or reprotoxic substances. Exposure could directly occur during experimental procedures like the administration of substances, but also indirectly during handling and cage change of the animals.

Most of the animals the vivarium lab personnel work with have specific pathogen free (SPF) status or origin. Moreover, many models involve immune-compromised or immune-deficient animals who can quickly become infected with microorganisms unless adequate protective measures are applied. Such infections can emanate from animal care staff/researchers, non-sterile biological products used, but also from other animals/cages. Infections can have severe effects on the health of individual animals and even can endanger the whole animal population. More often, these infections remain clinically invisible but have subtle impact on the outcome of experiments, such as a higher variability, change in the lifespan of animals, non-reproducible results, etc. Sometimes, these infections even make the animals useless for the intended experiments. For example, viral infections can occur without clinical symptoms but induce significant changes in the animals' immune system.

Precautions to protect animal care staff/researchers from animal allergies and toxic substances, and to protect the lab animals from infection risks can be taken at different levels: 1) the level of the building, barrier systems; 2) the animal housing, cage change/transport/cleaning systems; 3) procedures level; and 4) at a personal level by the use of personal protective equipment (PPE).

The second eBook of this series will discuss how building design, including appropriate heating, ventilation, and air conditioning (HVAC) and differential air pressure systems and barrier systems, can help to protect humans and animals. This article—and eBook—will discuss the most frequently used types of animal housing systems and equipment for cage change and animal procedures, including how and to what level they help to protect animals and animal care staff and researchers.

Animal Housing Systems

Open Cages

Traditionally, cages with a wire-bar lid are used for housing mice and rats. Because there is a free flow of air between the inside of a cage and the room, these cages are also called "open" cages. The free flow of air, dust particles, aerosols and vapors can quickly spread from the inside of cages into the room environment. The more air movement occurs in and around the cage, the higher the chance of spreading the contents of the cage into the room environment. Risks are known to be highest during animal handling and changing and cleaning of dirty cages. If used, animal care staff and researchers can be easily exposed to animal allergens and possibly toxic research substances. Additionally, there is no animal protection against unwanted microbes from humans and other (infected) animals/cages. Therefore, infections can quickly spread between cages and are very difficult to control. Microorganisms that spread by air have caused dramatic effects on research results and continuity of animal colonies in setups with open cages and "open handling" of animals and dirty cages.

Innovive's universal Innocage® mouse cage bottom fits all Innocage® mouse cage lids, feeders, and watering solutions.

Typically, animals housed in open cages are handled open on a bench or trolly, and cage changes are performed without any protection. This causes a significant increase in dust particles in the air that transport microorganisms and allergens, especially during the stacking of dirty cages. If open cages and open" animal handling are applied, protection of animal care staff against lab animal allergens can be reached, to a certain extent, with PPE like a coverall, shoe covers, gloves and facemask. From an occupational health and safety (OHS) perspective, building construction, infrastructure, equipment and working procedures should be considered and applied first to reduce OHS risks if possible and feasible. However, PPE should only be considered the first line of defense if protection at other levels is not possible or reasonable. Despite these drawbacks, open cage systems are often used, especially in animal behavior research and toxicology settings. The method is also used in large scale SPF/SOPF breeding facilities of immunocompetent rodents in combination with stringent hygiene barriers, PPE and dedicated animal care staff.

Due to the free flow of air, open cages are neither suitable to house immune-compromised mice nor avoid potential contamination of animals with microorganisms from vivarium workers. If using an open cage, one option is to cover the cage with a closed filtertop. Typically, a Remay filter is used in these tops, preventing dust particles that can "fall" into the cage but allow some exchange of gases (oxygen, CO_2, ammonia) via passive diffusion. However, the ventilation is limited, resulting in an earlier rise of higher ammonia and humidity levels. As a consequence, these filtertop cages should be changed more frequently compared to open cages.

Individual Ventilated Cages

To overcome the poor ventilation in static filtertops, a few decades ago, the Individual Ventilated Cages (IVC) concept was introduced. IVC systems are cages with closed lids and a filter at the top. Each cage has its own air supply and exhaust. The inlet and exhaust air of the system is HEPA-filtered. The result is much better air quality with significantly lower allergen levels. Additionally, an IVC can be connected to the lab's exhaust system, further removing allergens and odor from the room. Because the HEPA filtration of the in- and out-going air of the animal cages filter out microorganisms, the infection risk (of airborne microorganisms) is significantly reduced when cages are closed. During cage changing and procedures with animals, cages must be opened, stacked, transported, emptied and cleaned in the cage wash area only. Unless adequate protection measures are applied (both equipment and working procedures), open handling of animals and used cages will result in a temporary increase of animal and cage dust in the air, again implying higher levels of allergens and microorganisms (higher infection risk of animals/cages/personnel).

Animal Transfer Stations (ATS) & Class II Biosafety Cabinets (BSC)

Several primary engineering controls have been developed to protect vivarium technicians during the handling of animals and cages. The Animal Transfer Station (ATS) and Class II Biosafety Cabinet (BSC) are used for this purpose. Sometimes fume hoods and backdraft cabinets are also applied to protect

Innovive's Innorack® IVC Mouse 3.5 dynamically maintains settings on both supply and exhaust blowers.

NuAire's AllerGard™ ES (Energy Saver) model NU-620 Animal Transfer Station offers product and improved allergen protection during sensitive cage changing procedures, while maintaining mobility in the vivarium environment.

personnel, as well as HEPA-filtered downflow modules/units. ATS's and BSC's protection principles are comparable: both provide a laminar (unidirectional) downflow of HEPA-filtered air in the work area where the IVC cage is opened and animals are handled to ensure product protection. However, an ATS is specifically designed for changing cages of non-infected rodents. An ATS only provides protection from most allergens.

In contrast, a Class II BSC is designed to provide a high level of personnel protection (for you and those around you), product protection (for your samples), and environmental protection (for the room). A BSC must meet Class II international standards for containment performance. To meet these high standards, a Class II BSC needs to be designed and manufactured to specific construction and performance criteria. Historically, BSC's were primarily designed for microbiological research, and not for lab animal work. However, many BSCs described as "Animal Handling BSCs" have been modified to meet the animal researcher's specific needs.

In contrast, when it comes to an ATS, there are no specific standards they are designed to. Each manufacturer can approach the design of their cabinet as they see fit. An ATS can be designed to be accessible from one or two sides. This provides high ease-of-use and allows for the cages/workspace to be accessed from all sides, enabling a high level of productivity (i.e., technicians doing cage changing often need to change out hundreds of cages per week). For the ease of bringing in larger cages, the sash opening height of an ATS is typically 14 inches (356 mm), whereas the maximum on a BSC generally is 12 inches (305 mm). Furthermore, an ATS has a smaller footprint, is less cumbersome, offers height adjustability, and is mobile to enable movement between IVC racks and animal rooms. This makes an ATS very versatile and widespread for general (low-risk) use.

Use of a Class II BSC is required where a higher level of protection is needed, or the animal's status is unknown. They are used typically when working with Biosafety level 2 (BSL-2) microorganisms (wildtype as well as genetically modified) to protect the operator, the animals, and the environment. It can be advisable to use a BSC when the risk of infection of the animals should be minimized, e.g., in case of immune-deficient animals and other animal experiments that can easily be disturbed by unwanted microorganisms.

BSC's used for animal procedural work were initially developed for in vitro procedures to protect personnel, product and environment. Later on, BSCs were redesigned and modified to facilitate working with animals and IVCs.

NuAire's LabGard® ES NU-677 Class II, Type A2 Animal Handling Biosafety Cabinet can accommodate the largest mouse and rat cages.

A BSC, by definition, is only open on one side and traditionally has an access opening height of 8 or 10-inches (203 or 254 mm). BSCs designed for animal handling need to offer a larger access opening of 12-inches (305 mm) or more to permit the movement of IVC cages in and out of the work zone. The larger access opening allows a technician to reach over the tops of cages to remove lids easily and access the interior of the cage. The added room to move arms freely above the cage allows the technician to keep arms parallel in the sterile work zone. Arms movements that involved an incline increase the risk of air traveling down the arm and out of the cabinet's front. To ensure that Class II personnel and product protection are maintained, the user needs to be protected by a 100 FPM (0.53 micro-siemens) air barrier through the access opening. Animal handling BSCs often feature pre-filtration systems to capture large particulates such as animal hair and dander to extend the supply and Exhaust HEPA filters' life. BSCs are available in different sizes; 4, 5, or 6-feet (1.2, 1.6, or 1.8 m) wide. Often the room size determines what size BSC can be used.

Most BSCs used for animal work are height-adjustable and have casters for mobility for some movement and cleaning. If they are intended to be used in alternate locations, each location must be identified, and the BSC certified for proper function in each area.

Although working in an ATS and BSC may seem similar, each requires specific training. Strict standard operating procedures (SOPs) should be followed to maintain the safety level (biocontainment and bioexclusion) needed. BSCs are designed to provide a higher level of safety and are used for higher-risk situations compared to ATSs, which are intended for lower-risk applications. As a consequence, it may seem more complex to work in a BSC. However, one should keep in mind that following less strict work-procedures in an AST results in a higher risk of infections, cross-contamination, and exposure to lab animal allergens.

Laboratory animal allergen (LAA) is probably the most prominent OHS health risk in a lab animal facility. Particular attention should be paid to reduce the risk of exposing people during cage change, transport of used cages, bottles, cage enrichment and discarding of used bedding and disposables. When working in an ATS or BSC, attention to safety remains necessary. For instance, the following two routine procedures pose exposure risk for the operators unless safety precautions are brought in place: 1) when removing a cage without a lid or cover from an ATS or BSC, the downflow air is pushed into and out of the cage while moving it out of the instrument, blowing dust-containing allergens and possibly microorganisms into the breathing zone of the vivarium worker; 2) the other often neglected procedure is the stacking of dirty cages outside the ATS or BSC. Every time a cage is added to the stack, it pushes the air from the inside of the dirty cage out into the environment. The air from the dirty cages contains a high amount of dust particles with lab animal allergens and—depending on the experiment—other potentially hazardous agents. For this reason, it is recommended (and in the case of BSL or higher conditions, required) to stack cages inside the ATS or BSC. Also, care should be taken when stacks of dirty cages, used lids, tops, etc., are removed from the ATS or BSC.

To circumvent these issues by stacking of cages, a so-called "full cage change" regimen could be used. In this process, a dirty cage, lid and top are reassembled before it is removed from the AST or BSC and transported to the washing area. Compared to fully assembled IVCs (cage and closed lid), stacked cages takes far less volume per cage. As a consequence, transport and storage of stacked cages are far more efficient.

As an alternative to the full cage change, dirty cages can be stacked and bagged (as can other materials) before removing them from the AST or BSC. This is especially effective for single-use cages due to their high stacking density. Typically, a stack of 25 single-use cages/lids is 20 inches tall. A full stack of single-use clean cages or bagged dirty cages can be introduced or removed from an AST or BSC stack in a single movement. Lastly, the transport of dirty cages and other rodent housing materials should be performed in a contained way. The washing area also needs special attention as it is there that cages are unstacked, enrichment and nest material are removed, and the bedding is dumped. If no preventive measures are taken, this can cause high exposure to allergens and other hazardous agents.

Besides changing cages, a variety of procedures can be performed on animals during experiments, e.g., taking biopsies for genotyping, blood sampling, aseptic surgeries, tumor measurements, etc., including the use of anesthetic gasses or carcinogenic/toxic compounds. To protect staff from hazardous agents (including allergens), these procedures should be done inside a Class II BSC that is connected to the building exhaust system. All particles and volatile compounds will either be captured within the BSC filters or be removed from the room/building via the exhaust of the building ventilation system. For researchers who need unique experimental setups, vendors can provide custom made/designed BSCs, e.g., with integrated microscopes or heating plates to solve the demands from the research community. In certain circumstances, HEPA filter downflow module/units can be used to protect personnel and animals against hazardous substances. These units create a unidirectional downflow of HEPA filter air from top to floor or work surface. Depending on their size and construction, they can protect large surfaces for animal handling, cage changing procedures and dump stations.

Isolators

Although IVC will reduce allergen exposure and the infection risk, these cages are not 100% airtight and must be opened for cage change and animal procedures that increase contamination risk of the staff, the animals and the environment. For some type of work, more stringent barriers are necessary. In these situations, isolator systems, which can provide absolute barriers, must be used. Isolators can be made of flexible film, plexiglass, or stainless steel combined with safety glass. Both the supply and exhaust air are generally HEPA filtered. In an isolator, animals are housed in open cages. For the introduction and removal of materials (feed, water, bedding and other materials needed), a unique material sluice is used to prevent breaking the barrier. Depending on the animal study, materials must be sterilized before introduction into or after removal from the isolator as must the isolator itself. Within the wall of the isolators, long sleeves are mounted for handling the animals and cages and to perform animal procedures.

Portable isolator systems are ideal for both acute and chronic holding of animals.

Isolators can be equipped with particular docking ports for docking to a biosafety cabinet or a second isolator so animals can be moved between an isolator and a BSC for procedures that are not feasible within an isolator or between isolators. A determination as to which safety level/level of containment instrumentation is needed depends on the samples that need to be contained, as well as the safety level of the environment in which the procedures are performed. In the case of hazardous agents, a risk assessment must be completed and identified actions are accomplished before the study is started.

Isolators either run on positive or negative pressure. Positive pressure ensures that, in case of small holes (e.g., in a gasket, the flexible film or sleeves), no microorganism enters the isolator and thereby provides optimal bio-exclusion. Positive pressure isolators are mostly used for germ-free, nucleus breeding colonies and microbiome studies. Isolators run in negative pressure ensure that even in the case of small leaks, no air or microorganisms can escape from the isolator, ensuring optimal bio-containment.

Isolators either run on positive or negative pressure. Positive pressure ensures that, in case of small holes (e.g., in a gasket, the flexible film or sleeves), no microorganism enters the isolator and thereby provides optimal bio-exclusion. Positive pressure isolators are mostly used for germ-free, nucleus breeding colonies and microbiome studies. Isolators run in negative pressure ensure that no air or microorganisms can escape from the isolator, ensuring optimal bio-containment even in the case of small leaks.

Isolators are large and bulky (poor ergonomics, low number of animals/m2 or foot2), and all animals within an isolator must have the same microbiological level. This means that for experiments with test groups with different microorganisms, a separate isolator is needed for each test group. Furthermore, if there is a microbiological break in an isolator, the complete content should be considered as contaminated and potentially lost. Working with isolators demands a certain attitude, skill and experience. Therefore, isolators often have a dedicated team of animal care staff and are not easily accessible for other staff, including researchers.

Micro-Isolator cages

With increasing interest in germ-free animals comes an increase in microbiome studies and work with infectious and hazardous material, which needs a

Microisolator cages create a protective barrier at the cage-level.

higher protection level than standard IVCs provide. There was a clear need for more flexible, scalable systems that are accessible for researchers. Some vendors developed a specially designed IVC caging system with a higher containment level, referred to as micro-isolator sages. Such cages typically have HEPA air filtration on the individual cage level, are sufficiently airtight and can be submerged in disinfectant for external decontamination. By docking into an IVC rack, the valve for air supply and exhaust is opened. Micro-isolators should/must be opened and handled within the protective environment of a BSC Class II or higher, depending on the risk classification of the hazardous agents used and the results of a risk analysis.

As with isolators, there are two types of micro-isolators with crucial differences. One type has positive pressure for bio-exclusion studies—germ-free, Gnotobiotic animals, immune-suppressed animals, microbiome studies. The second type runs on negative pressure and can be used for animal experiments that need a high level of biocontainment, including BSL-III microorganisms.

Conclusion

Animal transfer stations and biosafety cabinets are an effective solution for vivarium workers that need protection from animal allergens, as well as instrumentation that provides good animal husbandry and care of animals. These containment instruments also minimize infection risk of personnel and positively impact study results, if used correctly. This article has provided an overview of the different types of rodent housing systems and equipment used for cage changing and procedures on animals, detailing how they protect animals, animal care staff, researchers and the overall laboratory environment.

About the Author

Marco Breuer Ph.D., *is a trained biologist, completing his Ph.D. at the Netherlands Cancer Institute. After his Ph.D., he set up a Transgenic Core Facility and became the head of the Animal Facility in the Leiden University Medical Center. In 2000, he earned his degree as an Animal Welfare Officer, and returned to the Netherlands Cancer Institute as head of the Animal Facility the following year. While there, he was responsible for the design and construction of a new high-end facility that was opened in 2014. In 2020, he also became head of the Animal Facility of the Netherlands Institute of Neuroscience. Breuer also works as a consultant.*

Infographic: Choose the Right Caging System for Your Needs

Are you working with infectious agents? Do you need to ensure your protection, but the product doesn't have to be sterile? Operating caging systems and/or changing devices above or below your experimental needs can be dangerous. It is important to understand the safety features of each type of equipment and consider their application to your research.

Level of Protection for Animals & Personnel: LOWEST → HIGHEST

Risk of Infection: HIGHEST → LOWEST

Level of Investment & Required Learning: LOWEST → HIGHEST

Caging System	Changing Device	Microbiological Level	Biosafety Class
Open cage	Bench	(Clean) Conventional	None BSL-I
IVC cage	Animal Transfer Station (ATS) Biosafety cabinet II	SPF S(O)F Immune deficient Infection exposure	BSL-II
Micro-isolator cage	Biosafety cabinet II	Gnotobiont Infection exposure	BSL-II BSL-III
Isolator	Biosafety cabinet III	Germfree Infection exposure	BSL-IV

BIG CAGE? Small Lab?

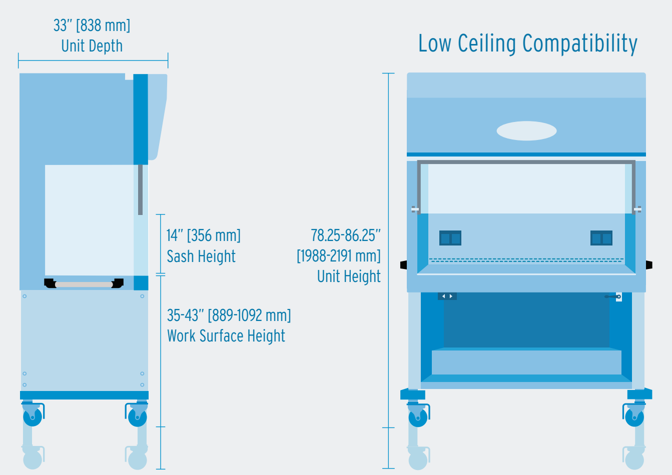
NO PROBLEM!

Introducing *The **NEW***

LABGARD ES LP

NU-640 CLASS II TYPE A2 ANIMAL HANDLING BIOSAFETY CABINET

- **Low Profile Console Model**
  for Low-Hanging Ceilings & Doorways
- **14″ [356 mm] Hinged Access Opening**
  Easily Fits Large Rat & Mouse Cages
- **Motorized Auto-Lift Base Stand**
  with Built-In Footrest & Heavy-Duty Casters
- **Single Mesh Pre-Filter**
  Easy to Remove, Clean, & Reuse
- **Work Tray Prop-Up Bar**
  for Easy Cleanability



Fits Through Standard Doorways

14″ [356 mm]
Hinged Access Opening

Work Tray Prop-up Bar
& Fabric Mesh Pre-filter

Request a Quote Online at www.nuaire.com or Call (763) 553-1270

NuAire, Inc. | 2100 Fernbrook Lane | Plymouth, MN 55447 | U.S.A. | www.nuaire.com

Ergonomic Needs and Trends in Vivarium Equipment

by Michelle Taylor

When the Occupational Safety and Health Administration (OSHA) officially recognized laboratory work as an occupation with risk for musculoskeletal disorders and repetitive stress injuries over a decade ago, no one working in a laboratory was surprised. Especially not vivarium researchers, who are all too familiar with the pins-and-needles of neck and shoulder pain following procedural work, cage cleaning or a long necropsy within the confines a Class II biosafety cabinet (BSC) or animal transfer station (ATS).

"The lab people are the last to complain, it's the old lab rat mentality," said James Koshy, director of the ergonomics division at Duke University (N.C.). "You are so results-orientated you don't pay attention to how you are physically feeling."

Long hours of procedural work inside a hood can be uncomfortable, but laboratory manufacturers have built in ergonomic features to help.

Scientists may not have been actively paying attention, but leading laboratory equipment manufacturers certainly were. To date, manufacturers have been diligent in incorporating top-notch ergonomic features, such as height adjustability and access opening holes, into new equipment design, while also providing solution-based accessories for retrofitting situations.

Height and Access: Two Critical Components

With about 2,400 laboratories spread across its campus, the University of California at Los Angeles (UCLA) has many scientists at risk for musculoskeletal disorders. That's why Randy Sauser, a certified professional ergonomist with UCLA Insurance & Risk Management, involves both laboratory manufacturers and research scientists in the laboratory design and ergonomic evaluation process.

"We know we are not necessarily experts in the laboratory area but we also know we are a part of the conversation, so we work with vendors to say 'this is what we are looking for, what do you have that can solve this need?'," Sauser said.

When designing, outfitting or retrofitting a laboratory at UCLA, Sauser provides researchers with a laboratory ergonomics checklist that offers ergonomic suggestions. For example, for Animal Transfer Stations and Biosafety Cabinets, the checklist suggests anti-fatigue mats for standing areas and correct sitting and standing posture. In fact, posture/position is the number one concern for those working within a cabinet for a prolonged period of time.

Height-adjustable equipment is critical to avoiding awkward posture positions and consequential pain. When searching for ergonomic options, those involved in capital equipment purchases should look for equipment that provides the maximum knee/thigh clearance. Combined with an adjustable chair with lumbar support and a footrest, these types of innovations are more comfortable and ensure correct posture. Some manufacturers, such as NuAire, even offer a variety of base stands from fixed to telescoping and automatically adjustable to add a higher level of personal customization.

Vivariums, especially those on university campuses, are accessible by many different researchers. For this reason, BSCs and ATSs with motorized height-adjustability are favorites—even necessities—within animal laboratories. To reduce stress on the shoulders, neck and arms, researchers of all heights need to be able to adjust the working height of their equipment, whether sitting or standing. For example, a necropsy can take more than an hour but can be accomplished while seated, so the cabinet needs to go low enough for a researcher to roll their chair under. Conversely, changing a mouse cage's bedding is a very active responsibility that sees most users standing and reaching—at a level that is comfortable and specific to them.

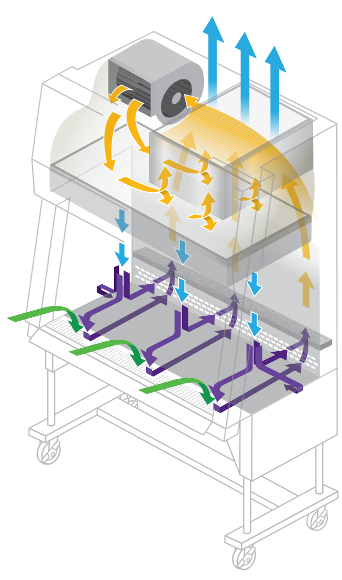
Vivarium space is often used for various purposes, meaning laboratories want their equipment to be versatile enough for lab animals and cell culture experimentation. Additionally, animal facilities need to be reconfigured much more frequently than standard laboratories. That's why all animal handling instrumentation and equipment must be on casters and able to fit through a standard doorway. It should be able to be turned freely and easily by someone of small stature to ensure any researcher can move equipment from one room to another when needed.

Height access opening is another critical factor in animal handling BSCs and ATSs. When working with animal cages, researchers need to seamlessly move them in and out of the work area, which requires a minimum of 12-] inches (305mm) for mice, 14 inches (355mm) for rats. The space is necessary to allow users to reach over the top of the cages to remove the lids for handling or changing of bedding/cleaning.

Model NU-640 feautres a built-in footrest and 14-inch (355 mm) access opening for working with large cages.

"We also encourage researchers to pre-arrange their experiment—give some thought to what it is you need for your task, and in which order, and then pre-arrange it that way," Koshy said. "Once you start working the chances of you trying to position or re-position things is low."

Of course, all of this movement and height accommodation must be done while still ensuring animal and personnel protection. Contaminated room air is pulled into a Class II Biosafety Cabinet through the front airflow grill by a motor blower. Air is pulled under the work surface and runs up the cabinet's back wall plenum and into the cabinet plenum. Depending on the Type of Biosafety Cabinet (A2, B1, or B2) this air can either recirculate back into the work zone or be exhausted. Air entering the work zone passes through a HEPA filter. The air is pushed in a unidirectional (laminar) downward motion through the work surface. Air is then split on the work surface being pulled back through the front grill, around the sides of the work surface, and through the back grill. Air follows the same pattern of being pulled up the back wall plenum and into the plenum again. Animal handling Biosafety Cabinets are specific because



In a Class II, Type A2 Biosafety Cabinet, contaminated room air is pulled through the front airflow grill by a motor blower, then under the work surface, up the cabinet's back wall, and into the cabinet plenum.

they feature a prefiltration system under the work surface or in the cabinet's back wall plenum to capture large particulates such as animal hair or dander. A pre-filtration system extends the life of the HEPA filters lowering the total cost of ownership.

The pre-filter needs to be checked and cleaned frequently. A prop up work tray can also make routine cleaning easier. A typical work tray can be propped up at a 45-degree angle, allowing a technician to clean underneath it without necessitating its complete removal. From an ergonomic standpoint, the kickstand is less stressful for animal lab workers to work with. A work tray is specific to an animal handling BSC. The work tray on a BSC designed for Biomedical or Microbioligcal work is dished to capture liquid in case of a spill. The work try of an Animal Handling Biosafety Cabinet is flat to allow for the easy entry and removal of cages.

Lights, vision, action

While height and reach are undoubtedly the main concerns, there are other characteristics of animal transfer stations and biosafety cabinets that make them ergonomic and comfortable to use.

"Contact stress, where the soft tissue in your hands or other parts of your body has its circulation cut off with a sharp edge, is a prominent area of concern," Koshy said. "Proper support that has rounder and softer edges helps."

In addition to facilitating cage changes, wide access openings help provide forearm comfort, while not disrupting airflow containment for personnel and product protection. A sloped armrest extension allows the forearm and elbow to be rested while holding up laboratory apparatus and/or cages while inside the work surface.

LED lighting, as seen in this NuAire Class II BSC, is easier on researchers' eyes.

A clear vision line and lighting in BSCs help reduce eye strain and further provide an effective work zone. A frameless, polished-edge window allows for enhanced visibility and better sight lines of the work surface area, meaning a researcher's eyes do not have to work as hard, nor do his neck and shoulder muscles since he does not have to struggle to look over or under a frame. Additionally, rather than harsh, bright light, cabinets should have cool white fluorescent lighting that avoids reflection and reduces glare from the stainless-steel work zone. From an illumination standpoint, LED lighting is easier on the eyes, and is also much more energy efficient. Researchers also want to ensure that lighting is positioned correctly, i.e., externally mounted, so it does not cast shadows on the work zone, nor does it fall right in front of the eye. Electronic ballasts can help minimize heat output within the work zone itself, as well as the overall laboratory.

"Lighting is a critical part because what happens is—no matter how well you train people—they will place their head and neck where they can see best," Koshy said. "If there is a glare coming off one corner or one part because the lighting is harsh from that side, researchers—even with the best chairs and footrests—will tilt their head to accommodate that light. So, diffuse lighting and well-placed lighting that fits the task is key."

And when we say lighting, we don't mean lighting for just the humans. Laboratory animals are just as susceptive to lights, and also have a stringent sleep cycle, sometimes based on research demands. To circumvent this problem, an extremely popular option is to use a BSC or ATS that has an integrated red light. As a species, mice cannot detect red light, so it will not disrupt them during sleep, or even act as a distraction when they are awake. Some units even come with the ability to set a timer, or to pre-program red lights for daily/weekly night research.

Commitment to health and safety

Of course, there is only so much equipment manufacturers can do to ensure a safe and ergonomic workflow—part of the burden undoubtedly falls on scientists and researchers themselves. Both Koshy and Sauser are quick to promote the value of stretching when dealing with prolonged work in the same position, which is an unfortunate attribute of scientific experiments.

"A lot of lab work involves prolonged work so your muscles are in the compressed or elevated level of activation for a long period of time," Koshy explained. "In these cases, we recommend anything that stretches out and elongates your muscles. Anything that involves improving circulation, blood flow and other fluids that will help elevate some of the muscle stress."

Standing at a BSC for long periods of time can result in the compression of muscles. Frequent breaks and stretching help elongate the muscles.

At UCLA, the recreation department offers a program called WorkFit, in which professionals will visit any department—including a campus laboratory—and design a stretching program designed specifically for the department's employees. The injuries and strain experienced by laboratory workers is complex and can be threatening to both their work and home life. Solutions like ergonomically designed animal transfer stations and BSCs are part of the solution. The other part is researchers' commitment to their own health, in the same way they are committed to their experimental results.

"What makes laboratory work hard is that there are often multiple risk factors. There is the posture risk, repetitive movement of small muscle joints, then there is the prolonged muscle work. It makes it an accumulative effect of ergonomic risk factors," Koshy said. "But this is their life calling. It's not something scientists and researchers can do for a few months and go off and do something else. So, they really have to look at their health from a long-term point of view, saying 'this is my profession. I need to do this, and it requires me to take steps the average person may not have to.'"

About the Author

***Michelle Taylor** is the Editor-in-Chief of the Laboratory Group. She can be reached at mtaylor@laboratoryequipment.com*

Ergonomic Equipment Checklist

- Use a chair with lumbar support that has adjustable height and angle
- Use footrests to support legs when seated
- Use anti-fatigue mats when standing for long periods of time
- Look for transfer stations and cabinets with cool white lighting
- Biosafety cabinets should have turntables inside them to support reach during procedural work
- Seek out adjustable height transfer stations and cabinets, especially if multiple researchers use the same equipment
- The glass on a hood or cabinet should be non-glare and tilted to provide a better work zone angle
- Take frequent micro-breaks and rotate tasks as much as possible
- Pre-arrange materials and workstation prior to start of cage changes or procedural work
- Remove any false fronts, drawers or supplies from under the work area

Ensuring Safe Practices in the Animal Laboratory

by Helen Kelly

Airflow Primary Engineering Controls (PECs) such as Biosafety Cabinets (BSC) in the Animal Laboratory serve as risk mitigation tools for some of the most precise workflows in the research world. To achieve maximum productivity and safety, it is essential to understand that each aspect of design contributes to a whole that can protect you, your work and your environment. To realize the benefits, laboratorians must adhere strictly to primary and secondary containment practices for each type of cabinet, lest the benefits of the equipment turn perilous.

Understanding Airflow Primary Engineering Controls

Animal transfer stations

An animal transfer station creates an air barrier at the front (and back based upon product design) of the cabinet through a vacuum created by a motor blower. The air barrier protects the technician from animal and cage bedding allergens. Unidirectional airflow flushes over the worksurface in a downward pattern to minimize cross-contamination in the work zone. Cross-contamination can be reduced by ensuring that animal cages are handled independently of one another, that there is adequate and separate space for clean and dirty cages, and there is adequate space for clean and dirty instruments within the work area. Adjacency is a key factor in reducing cross-contamination. Review the protocol—assemble everything you will need and confirm that you can safety move cages, bedding, and animals.

Biosafety cabinets

There are three classes of biological safety cabinets—and five subtypes under Class II—with principal differences in airflow ventilation systems and associated design requir ements. In a vivarium, the Type A2 and Type B2 are most commonly used Class II Biosafety Cabinets. The key difference among the types of Class II BSCs is the amount of air that is recirculated within the cabinet. Type A2 cabinets recirculates 70% of the air, while Type B2 cabinets recirculates 0% (total exhaust). Most Class II BSCs are not made to operate with flammable, toxic or explosive substances in the cabinet. A proper risk assessment must be performed to determine the proper Class II BSC type for a cabinet to be used with a minute to small quantities of volatile chemicals. It must be noted that Biosafety Cabinet applications involving volatiles must be exhausted through a facility's HVAC system. Your risk assessment will determine the proper Class and Type of BSC needed.

ATS vs. BSC

While animal transfer stations and biological safety cabinets look similar and share airflow concepts, the differences between them are critical to understanding which one is correct for your specific research. Animal transfer stations are easy-to-use and mobile, allowing ergonomic cage change processes while protecting both animals and personnel. Typically, an ATS is double-sided, and has a large sash opening [14 inches (354 mm)]. And while they are essential to any vivarium, they are not governed by any standards, meaning there's a wide range of variability in design and performance between manufacturers. Additionally, ATS units are usually not appropriate for work with biological hazard. On the other hand, a BSC is governed under the NSF/ANSI 49 Standard, which strictly enforces performance, design, testing and maintenance. BSCs also provide a level of animal and personnel protections that are not plausible with ATSs and can work with toxic and higher-risk agents (depending on class and type).

The work surface of an Animal Transfer Station (ATS) contains vacuum slots that pulls in air from around the work surface creating an air barrier. A single sided ATS features a stronger air barrier for improved containment.

Establishing a safe workplace

Knowing about safe working practice is only half the story. Putting safety into practice —even when you are distracted, tired, or feel overworked—is the road to mitigating risk. One approach focuses on behaviors and tools that reinforce safety engagement. Keeping them in mind helps to promote safety compliance, reduce errors and accidents, and moves individuals and organizations in the direction of establishing a safety culture.

"Where laboratory employees are the center of safety management, where workers are directly engaged in identifying procedures and validating processes, that's where you achieve a focus on optimum performance and the foundation for a safety culture," said Jan Wachter, Safety Program Coordinator at Indiana University of Pennsylvania.

When it comes to safety, Ian Olesen, Biosafety Expert at The Laboratory Safety Institute says, the what, the how and the why are equal partners in lab worker training.

"It's important for workers to learn the safety measures common to the different types of hoods on which they work, and also measures specific to each. That's one part. Understanding how each safety measure mitigates risk is equally important, which contributes to cooperation, and contributes to building a culture of safety," he said.

Protocols and Checklists

Protocol is always important in a workplace, especially so in areas where there is a risk of injury or death. A pilot doesn't skip his/her readiness steps—and neither should a laboratory technician.

The handling of animals, chemicals, and microbes requires precision. Following protocol at all times helps avoid incidents like animal scratches or bites, contamination, cross-contamination and chemical accidents. For example, when working in a biosafety cabinet, make three distinct spaces within the

The downward pattern of airflow significantly minimizes cross-contamination in the work zone.

cabinet to reduce the risk of drips, spills, and contamination. The ideal method in a Biomedical or Microbiological lab is to work from clean to dirty. When cage changing, this process is dictated by your facilities' SOP's and workflow. For instance, the materials needed to correctly cage change fill the work surface in a BSC or ATS quickly. A cage involves a clean cage and a dirty cage. You may also want to include a stack of clean cages within the sterile work zone along with feed, water source, enrichment materials, sterile spray, and more. You may also want to stack dirty cages within the BSC as well. The figure below shows a workflow with a clean area on the left

A workflow with a clean area on the left and right sides and a working zone in the middle.

and right sides and a working zone in the middle. Work with your facilities personnel or EHS department to determine the most appropriate workflow for your application. Space them correctly behind the sash, forward of the rear airflow grill, and with a specified amount of space between each. Be mindful of how you move your arms and hands among the three, what movements must be in and out only, and plan to avoid moving across with either hand from one space to the other. Ensure that no one will walk briskly behind you to disrupt the air flow.

Running all these thoughts through your head before or during testing can be taxing—and even cause a serious mental mistake. Thus, multiple safety experts suggest creating a checklist not only for general laboratory safety, but for each specific project, as well. A general list ensures the entire laboratory is running safely and effectively, while a checklist for specific projects allows addendums and specifications to be taken into account.

If a checklist is a "do" list, Wachter also suggests a "don't list," as constructing the list helps promote mindfulness. Something to put in a Don't List are error precursors, or elements that can trigger mistakes. Some triggers are personal (are you worried by a careless colleague?); while some are organizational practices (a blame culture) and others, like ergonomic inefficiencies, are environmental. Error precursors are discoverable and often avoidable. When studying safety requirements, identify error precursors and possible ways to address them.

Due diligence

The manufacturer designed equipment to protect you, your work and your space. Detailed knowledge about the design provides a context for understanding the safety measures associated with each. Study the manufacturer's illustrated manual and identify each part on the equipment as you read. It's sometimes helpful to explain to someone else what the parts are, how they work together, and the safety practices required when using the equipment.

Manufacturers are subject matter experts, especially when it comes to their own equipment. If at any point you have a question, don't hesitate to reach out to the manufacturer of the hood, cabinet or animal transfer station you are working with.

Case Study: The Institute for Health Science Research Germans Trias i Pujol (IGTP)

Awareness, knowledge, understanding and direct experience, along with practical work load and accommodating facility design, all help promote safe laboratory practices.

"In our culture, where our work is ABSL1 to ABSL3, everyone must know the equipment, recognize the invisibility of infectious agents, the unpredictability of the animals, the complexity of procedures, the risks and the consequences of error and also equally the joy they experience being a trusted, valued member of our team," Sara Capdevila-Larripa, who teaches Laboratory Animal Science and Welfare at the University of Barcelona and also works at The Institute for Health Science Research Germans Trias i Pujol. "We need to check filters; on the animal transfer stations, we need to change one cage at a time, protect contents inside and avoid infection from the outside. We may have a small space and work may be uncomfortable. We must do our best to avoid back injury, and value all ergonomic alerts."

Jorge Diaz-Pedroza, manager of the ABSL3 Unit at IGTP offers examples of safety requirements he most often sees breached. Some errors can be avoided by regular review of safety requirements and by making routine ergonomic adjustments. His checklist is as follows:

To reduce cross-contamination:

Disinfect rigorously before, after, sometimes during work. Know and respect the exposure requirements of each disinfectant. For example, dwell time for ethanol is 1 min, while dwell time for peroxide is 6 min before wiping down the surface.

Check that nothing shadows the UV light and confirm live time effectiveness annually. Blue does not mean that it disinfects.

Ideally, each time you work with a mouse cage, take new gloves. If, with the COVID-19 pandemic, new gloves for each mouse cage in are not affordable, carefully and thoroughly disinfect gloves with 70% ethanol, and change gloves if there is a tear.

Do not reuse diet or water from one cage to another.

When working with specific pathogen-free (SPF) animals, do not work with mice from different cages at the same time. It may seem to save time but the risk of cross-contamination is high.

Do not add clean material to a changing station where you are already working.

To protect staff and animals:

Switch biosafety cabinets on, then wait 10 to 15 minutes before operation. This is the time required for cabinets to create the air barrier that protects the operator from the cabinet contents.

Make sure sleeves stay inside gloves and later that you dispose of them safely. The movement of the arms and hands in and out can cause the junction between the glove and the lab coat to slip, exposing the skin of the wrist. Before starting to work, tape the glove where it meets the sleeve. Use different colors for gloves that come into direct contact with infectious agents.

Keep the amount of caging material to the recommended levels. Too much can block the air exhaust that creates the safety barrier.

Confirm you have space in your work area close to the cabinet for diet, clean cages, dirty cages, water bottles. The work flow must allow you to work properly within the safety rules.

Allow the cabinet to do its job. Working with animals and small instruments behind a screen can be uncomfortable. For example, when you inject a treatment in the vein of a mouse, take a blood sample, or do a biopsy or necropsy, you work at a distance and your body positions are dictated by the screen. But opening the screen exposes you. To protect the worker, keep the glass screen at the requisite level; never open.

Most mistakes are caused by work load and training, says Rosa Maria Ampudia-Carrasco, manager of one of the SPF units at IGTP.

"What we learn in a document about preventing cross-contamination and accidents is the ideal. When we implement procedures in the animal facility, we need to consider the extent the environment supports safety, for example in movement of animals, samples and materials. Before starting to work with infectious diseases, or with biological agents, a simulation with the research team and the animal technicians helps to ensure that everything is done properly," Ampudia-Carrasco said.

IGTP splits their training into three parts—know the equipment; know the safety requirements; and, work on the job with an experienced technician. Along the way, they encourage staff to ask questions and make suggestions.

"Human error is not avoidable but we can work all the time to reduce it, mitigating risk, strengthening our culture and improve job satisfaction," Capdevila-Larripa said.

About the Author

Helen Kelly is a Colorado-based freelance writer covering science and management. She has also authored multiple books on nutrition.

20-1577-W-G-EN-1-1220