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Innovative win-win research workplace strategies

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Ergonomics

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contents

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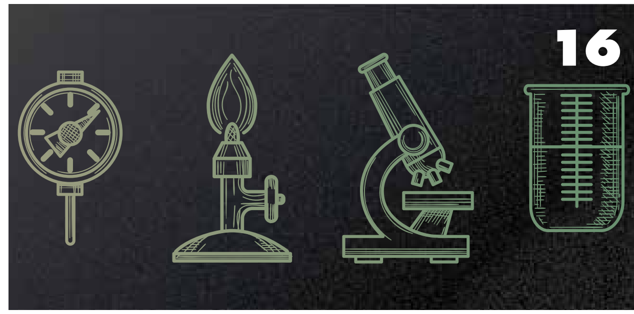

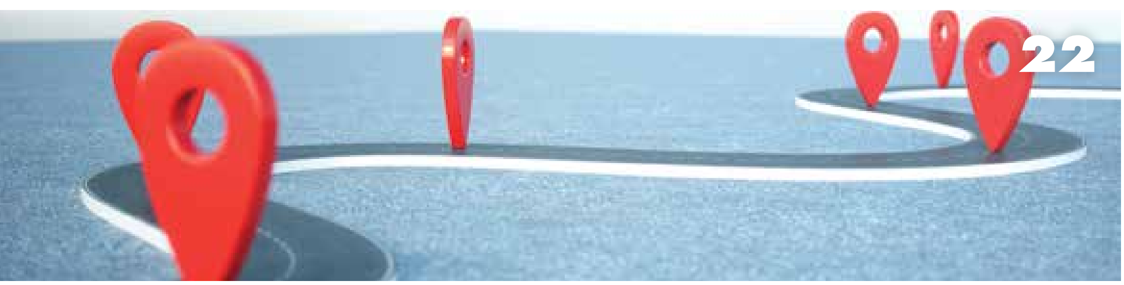

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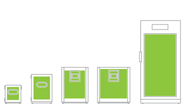

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1) Baker, Monya. "1,500 scientists lift the lid on reproducibility." Nature, no. 533 (May 26, 2016): 452-54. doi:10.1038/533452a.

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SHARE YOUR THOUGHTS ON DESIGN

Our Lab Design Summit in May will not only be an opportunity for you to meet and network with other lab managers and those in the laboratory design/build world, but a chance to chat with our editorial team face-to-face about which lab design topics we should cover. Feel free to let us know how we're doing with our lab design content and share your ideas for what we could expand upon or change going forward. Join us in Atlanta May 11-13.

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BPA WORLDWIDE BUSINESS

DEPARTMENTS

the lab manager's role in lab design

Every lab manager will be involved in a lab design project at some point during their career (likely a few times), whether it is a renovation, a brand-new lab build, or a series of smaller-scale projects that aim to better utilize existing space and equipment.

The field of laboratory design has become a growing focus for *Lab Manager*'s editorial mission, particularly this past year with the addition of lab design editor MaryBeth DiDonna joining the team, and the launch of *Lab Manager*'s third live event, the Lab Design Summit, taking place May 11-13 in Atlanta, GA (turn to page 34 for more details on the Summit).

Lab design encompasses many topics beyond traditional renovations or new construction projects, including sustainability and efficiency, how to enhance existing spaces, and future-proofing facilities. Additionally, there's a diverse group of minds involved in any lab design project, from architect, project manager, or design consultant, to the facilities manager. The lab manager often acts as the liaison source between these numerous disciplines to ensure the needs of the lab staff are being met, while also keeping the project on track, on budget, and with minimal disturbance to workflow. This issue will help lab managers navigate the design and renovation process, and may spark some ideas on how to implement small-scale enhancements to your facility that can have a big impact.

The cover story, "Optimizing Lab Spaces," discusses ways to take advantage of lab design to appeal to existing staff, new recruits, and upper management, using a newly designed building at Arizona State University as a prime example. Author Gary Cabo outlines the design process, beginning with developing a mission statement for the outcome of the project, to then creating a "neighborhood" open layout of lab spaces, maximizing the facility's footprint, and incorporating specific design elements to increase productivity and encourage thoughtful collaboration. Turn to page 8 to learn more about this project.

For some research groups, a stationary laboratory facility simply does not suffice. For this issue's lab design feature, we profile three mobile labs—a mitochondria lab housed in an RV; an all-electric surgical instrument lab built from a ULCA and Winnebago Industries partnership; and a marine research sea vessel. Each of these lab groups had unique needs to properly conduct their research, and found that the ability to be mobile was a key factor in successfully completing their work. Turn to page 26 to read the full article.

This issue's Health & Safety section (page 30) also includes a lab design twist, focusing on the importance of indoor air quality. Without proper ventilation, safety standards, and regular evaluation, the health of laboratory staff could be at risk. *Lab Manager*'s designated "Safety Guy" Vince McLeod shares knowledge from organizations like OSHA and the EPA, and also includes his advice from years of experience with developing protocols for regular indoor air quality assessments. "By surveying your indoor air quality regularly, you can find and prevent many common problems before they become serious," he says.

Enjoy,

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Optimizing Lab Spaces

Innovative win-win research workplace strategies

by Gary Cabo, AIA, LEED AP®

▲The design and scale of the new, copper-enclosed laboratory building at Arizona State University creates a dramatic sense of arrival at a major campus gateway, its primary form an expression of the three research "neighborhoods" that comprise each floor. *Credit: Nick Merrick © Hall + Merrick*

Workplace strategy may not be the first thing that comes to mind in the design of a laboratory building; however, it is an essential element in the creation of a productive and efficient research environment. After all, laboratory work is only one part of the research process and—just like any other industry—when it comes to the recruitment and retention of top talent, individuals are certainly considering the total work setting when assessing new opportunities. The key to workplace strategy success is to create an environment that will be a win-win for researchers and for the client/owner alike. Cost, maintenance, and spatial efficiencies must be baked into the design, while principal investigators should be encouraged to develop a sense of ownership over their space through options to customize it to their needs. This article highlights Arizona State University's (ASU) Biodesign Institute C as a case study in workplace strategy success.

"Aspirations for the project were set very high and defined in a project mission statement that included key targets for measuring success."

Big goals, big results

From the outset, ASU intended for the Biodesign Institute C building to make a powerful visual statement at a campus gateway, set a new bar for sustainability and spatial efficiency, and serve as a new venue for groundbreaking scientific discovery to take place. Aspirations for the project were set very high and defined in a project mission statement that included key targets for measuring success. The essence of the statement was for the university and the project team to deliver a new research building that provided highly flexible and adaptable space for reliable research, balanced first cost with lifecycle cost, and offered the maximum research space for the investment. ASU challenged the project team to work within stipulated space constraints to create a dense program of varied workspace options that would promote

and enable the creation of collaborative research clusters, while increasing opportunities for chance interactions between different research groups. In order to develop optimal programming options, the design team consulted with a diverse range of people, from furniture vendors to representative user groups.

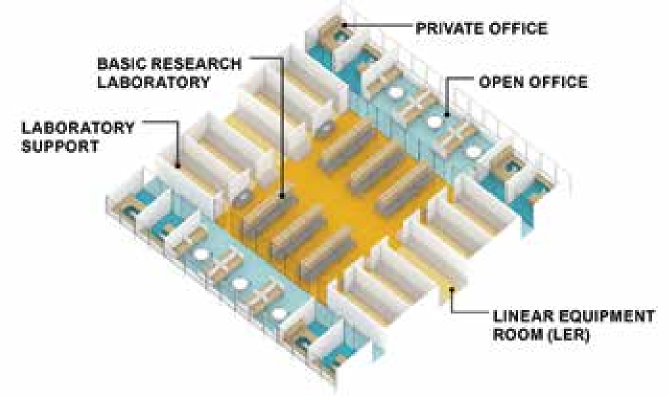
The resulting 191,035 square-foot building was intentionally designed with an open neighborhood model to encourage collaboration between scientists of different disciplines. But in order to truly maximize assignable space within the building, every square foot had to work smarter, not harder. Turning to the idea of creating a strategically symbiotic campus, the design team leveraged the proximity and accessibility of large public spaces within the neighboring Biodesign Institute A and B buildings, forgoing the addition of such spaces to Biodesign Institute C. This enables the new building to house the same number of principal investigators as the two neighboring research buildings combined, but in 40 percent less space and with a whopping 95.7 percent of usable square feet purely dedicated to research space.

The importance of elbow room

A neighborhood concept with open laboratories sized for six principal investigators was used to plan the laboratory spaces. For facilities, the neighborhood concept is successful because it increases profitable utilization of the laboratory space and turnover of researchers as appropriate. The concept also reduces first cost, energy, and long-term operations and maintenance costs. For researchers, this is a compelling solution because this layout increases opportunities for innovation, collaboration, and sharing of ideas as well as laboratory equipment. Biodesign Institute C comprises 13 research neighborhoods across the five above-grade levels—two are high-bay, two are chemical fume hood-intensive, and nine are basic experimentalist. With such a dense program and a lack of large public spaces, one might be forgiven for wondering if space feels a little tight. However, care was taken to ensure that the amount of space per researcher is more than comparable to that of other similar institutions. While vast atriums have been taken out of the equation, the concept of what collaboration space should look like has been reimagined and incorporated into each research neighborhood in an infinitely more useable, human-scale manner. Floor-to-ceiling vision glass encloses the laboratories, allowing for clear views of fellow researchers and easy monitoring of experiments from the immediately adjacent tech desk space; the physical proximity and strong visual connection between the two further enhances the sense of ample elbow room.

Sense of ownership improves output

In order to maximize assignable square footage and deliver on client expectations for a hyper-efficient laboratory building, traditional research workplace strategies were revised with a critical eye in favor of those that would promote maximum use of programmed office and tech desk areas. Frequently, the default furniture strategy at such institutions is to provide one desk for each person assigned to a laboratory. Keeping in mind that different researchers are productive in different types of spaces, coupled with the obvious fact that team members cannot physically be at the laboratory bench and their desk at the same time, the balance of furniture systems and layouts was fine-tuned to reflect the reality of the usage levels of the different neighborhood areas. This approach is a win for facilities as efficiencies are baked into the design from day one. As for the researchers, many workplace studies show that an employee's sense of ownership or control over their work and their environment has a positive and significant influence on their work performance, productivity, engagement, and ability to create and innovate. At Biodesign Institute C, research groups were able to tailor their neighborhoods to their individual needs and workstyles via a menu of heads-down and teaming options for office/write-up areas, ranging from standard desks to genius bars to living room-style seating arrangements. The ability to customize is an instant win for researchers, with positive ramifications for the owner/client, too.



▲The building's open neighborhood model encourages collaboration between scientists of different disciplines. *Credit: ZGF*

Increasing productivity, naturally

Biodesign Institute C's biophilic design elements are intended to foster a positive, productive indoor environment, while maintaining connection with nature and community. A 35 percent window-to-wall ratio and transparent layering of research spaces ensures daylight floods above-grade interiors. Abundant windows on each level, including the glass-enclosed lobby, overlook active campus thoroughfares and a grove of vibrant palo verde trees.

> "The ability to customize is an instant win for researchers, with positive ramifications for the owner/client, too."

The building's striking dual façade of copper screen and insulated metal panels was not just an aesthetic choice. Comprised of thousands of copper panels, the screen features eight different levels of perforation. Intensive studies of the site's micro-climate and façade-specific conditions informed their calibration and positioning to minimize solar heat gain, optimize daylighting and visual comfort, and provide unobstructed views. A two-foot gap between the insulated metal panels and the copper screen, coupled with openings in the screen, creates a ventilated cavity where air temperature between the two skins is balanced with the outdoor air temperature. As a shading device, the screen reduces the surface temperature of the inner façade by roughly 65 degrees on hot summer days. This in turn reduces the interior surface temperature of the wall by three degrees, significantly reducing the cooling load on perimeter spaces and further contributing to user comfort.

Inside the building, the project team worked with the university to enact new standards for reduced air change rates, supporting use of a chilled beam hydronic system where ventilation is decoupled from cooling. All non-laboratory air cascades from perimeter offices through the laboratories, providing "free" air conditioning for office spaces and reusing the air to meet laboratory ventilation requirements. Variable volume low-flow fume hoods further minimize air change rates while lowering turbulence, thus increasing user safety. As a result, air quality is high *and* the facility is projected to set new standards of energy efficiency for campus laboratory buildings, with a predicted 81 percent energy use reduction over the Labs21 baseline.

▲Highly flexible yet densely programmed laboratory space is enclosed in floor-to-ceiling vision glass, allowing for clear views of fellow researchers and easy monitoring of experiments from the immediately adjacent computational space. *Credit: Nick Merrick © Hall + Merrick*

Arizona State University intended for Biodesign Institute C to make a powerful statement at a campus gateway and serve as a new venue for groundbreaking scientific discovery, while simultaneously raising the bar for sustainability and spatial optimization. By leveraging the existing public spaces and amenities of neighboring buildings, research neighborhoods were densified smartly, without depriving teams of collaboration space or elbow room. A logical reassessment of space and seating led to a win-win design with both workflow and spatial efficiencies baked in to benefit the bottom line for facilities, while incorporating a controlled set of customization options that provide researchers with a valuable sense of ownership over their space. The new research environment within Biodesign Institute C is not only highly efficient in every way, but also mutually beneficial for the university and researchers alike.

***Gary Cabo**, principal at ZGF Architects has 36 years of experience leading large project teams in the execution of innovative design solutions for technologically and programmatically complex research buildings. His involvement on projects extends from initial design through construction administration, working closely with clients, architects, and engineers to resolve technical design issues and develop design documentation. Gary received a bachelor of environmental design from Miami University, and a master of architecture from the University of Minnesota.*

labs less ordinary

Purdue University's Ray W. Herrick Laboratories

"LIVING LABS" SHOW HOW BUILDING DESIGN CAN INFLUENCE HUMAN COMFORT AND PRODUCTIVITY by Lauren Everett

On average, Americans spend about 90 percent of their time indoors, where the concentrations of some pollutants can be two to five times higher than typical outdoor concentrations, according to an EPA report. So, how is human health affected by an indoor lifestyle?

> "Almost any type of heating, air conditioning, ventilation, [or] refrigeration system around the world has something in it that has been designed by our laboratories."

"If you're going to be in these [indoor] spaces for long periods of time, what impact, if any, will these spaces have on your health? What can we do to make these spaces healthier and more pleasant in other ways?" These are the types of questions that Jeff Rhoads, director of the Ray W. Herrick Laboratories at Purdue University (West Lafayette, IN), and fellow researchers are evaluating.

As Rhoads explains, the Herrick Labs facility is "eclectic"—housing a variety of basic and applied research centers associated with mechanical engineering and related disciplines. One such example is the Center for High Performance Buildings. "We look at indoor air quality, various technologies that we can put into spaces to make them more livable, how to be more energy efficient, and other things like that," says Rhoads. "Purdue has a long history of working with equipment companies and building material companies to bring the next thing out to market. These products need innovation and validation based upon basic research. If you put something in a commercial building, you expect to interact with it for decades," he adds. Teams at the Center for High Performance Buildings partner with industry to create new technologies in sustainable building systems, indoor environments, human perception and comfort, and high-performance equipment. "Almost any type of heating, air conditioning, ventilation, [or] refrigeration system around the world has something in it that has been designed by our laboratories," says Rhoads, adding that the same is true for noise control systems as well.

▲The new Ray W. Herrick Laboratories, opened in 2013. *Credit: Herrick Labs Archival Photo*

Evaluating indoor air quality

The Herrick Labs offer 83,000 square feet of space for students, faculty, and industry. Some of the spaces and features of the building include advanced engine test cells; acoustics, noise, and vibration testing; and an


People
behind
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1. Original Herrick Labs, donated to Purdue University in 1957 by Ray W. Herrick. *Credit: Herrick Labs Archival Photo* **2.** A Herrick Labs student working in the High Bay Testing Area of the facility. *Credit: Marketing & Media, Purdue University* **3.** A study in a tightly-controlled office space at Purdue University is showing that people greatly impact the air chemistry of the rooms where they work. *Credit: Purdue University/Brandon Boor* **4.** Students studying in the Living Labs at the Ray W. Herrick Laboratories. *Credit: Marketing & Media, Purdue University*

innovative perception-based engineering lab. Herrick Labs has a more than 60-year history of conducting work that has a real-world impact, which for Rhoads, is what drew him to the facility. He has been a Purdue faculty member since 2007, but just recently took on the leadership role as director of Herrick Labs in the fall of 2019. "As a researcher that has spent a lot of time in academia, I have come to learn that it's not always the case where you can see things happen at a lab bench that then goes on to directly impact society. That's what you hope, but you don't always see those success cases. But in my job, I see it on a daily basis."

Another unique facility under the Herrick Laboratories umbrella is a space known as the Living Labs. Inspired to learn more about indoor contaminants, lighting, and thermal comfort within office settings, researchers created a tightly-controlled set of four open-plan office spaces equipped with many sensors that track the flow of indoor and outdoor air through the ventilation system, amongst other pertinent measures. The goal of one key study? To identify all of the types of indoor air contaminants and recommend ways to control them through how a building is designed and operated. This effort is one of the largest studies of its kind, according to Purdue.

As Rhoads explains, the four Living Labs offices can each be customized or reconfigured. "We can change the ventilation in the room and do tests on how humans perceive that. We can do controls or experiments side-by-side since we have four nearly-identical rooms and we can do different interventions in each one," he says. "As you can imagine, it's a unique space to design, and requires a lot of forethought."

In addition to the sensors, the team deployed a proton transfer reaction time-of-flight mass spectrometer to identify compounds in human breath in real time. They found that isoprene and other volatile compounds linger in the office air even after people have left the room. "Our preliminary results suggest that people are the dominant source of volatile organic compounds in a modern office environment," explains Brandon Boor, assistant professor

of civil engineering, in a Purdue press release on the study. “If an office space is not properly ventilated, these volatile compounds may adversely affect worker health and productivity.” As you may expect, the more people in a room means more emissions of these compounds. Although this study focused on office workspaces, indoor air pollutants and proper ventilation is a concern in any indoor space, particularly laboratories.

“A large fraction of energy consumption in this country is spent on heating, cooling, ventilation of buildings, and small changes in the way we design our windows, furnaces, or air conditioners can have tremendous global impact in terms of environment, human health, etc.,” says Rhoads.

How is lab design evolving?

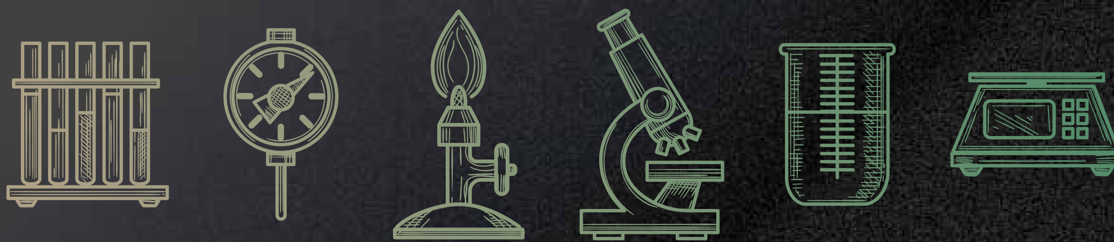
When it comes to the evolution of laboratory design, Rhoads notes that he has observed the increasing importance of flexible space and the reallocation of space. “In the research world, we’ve gone from having a somewhat clear direction of what comes next, to the need to have space that can be turned over quickly from one big project to the next,” he says. “So, we’re having to spend more time designing in flexible utilities.”

From an efficiency and productivity standpoint, Rhoads has a special focus on the layout of the lab and furniture choices. “How do you place your engineer, students, etc. in proximity to their experimental apparatus? There’s certainly pros and cons associated with that,” he explains. “Debating different things like flexible or fixed office seating—these are things I deal with on a fairly regular basis that I think are huge players when designing new lab spaces.”

As for the future of design and engineering, and the next direction of research at Herrick Labs, Rhoads and his team are certainly thinking outside the box. They are currently involved in a NASA project that aims to develop transformative smart autonomous habitats that can withstand and adapt to unpredictable deep space environments. Rhoads also hopes to expand Herrick Labs’ engagement with agencies like the Department of Defense and Department of Energy, and continue to better understand the interface of buildings and other mechanical systems and people.

“Autonomous buildings and vehicles are certainly hot topics that we’re engaged with at the research level, so thinking about those spaces, how to replicate them, interact with them—those are challenges we enjoy tackling on a daily basis,” says Rhoads.

***Lauren Everett**, managing editor for* Lab Manager, *can be reached at leverett@labmanager.com or 973-721-4070.*



The Design Evolution of Common Lab Supplies

A LOOK BACK AT HOW LAB EQUIPMENT HAS TRANSFORMED THROUGHOUT THE YEARS, AND A GLIMPSE OF FUTURE TRENDS **by Andy Tay**

"Using a micro-pipette, add trypsin into the cell culture flask and wait for five minutes. Check that the cells are detached before transferring the cell suspension into a Falcon tube. Next, centrifuge the Falcon tube for five minutes. Finally, count the cell density using a hemocytometer and transfer desired numbers of cells back into the culture flask."

Does this protocol for cell culture look familiar? What about the lab supplies listed in the protocol? Lab supplies such as micro-pipettes and cell culture flasks are so common that no researcher pays much attention to them anymore. However, unknown to many, the designs of common lab supplies have evolved tremendously to suit modern scientific endeavors. Their sophisticated and standardized designs have enabled protocols to be rigorously established—a major factor driving scientific progress. This article outlines the chronological evolution of popular lab consumables and equipment, and discusses future developments in their designs.

Centrifuges

A centrifuge is a piece of equipment that makes use of centrifugal forces to separate substances based on their densities. This rotation-based mechanism causes denser substances to be collected at the bottom while less dense substances rise to the top.

As early as 1864, driven by the commercial need of the dairy industry to quickly separate cream from denser milk, the German brewer Antonin Prandtl invented the first dairy centrifuge. However, its rotational speed was inadequate for biomedical research as biomolecules are much smaller and lighter, and different species of biomolecules required faster speed to be separated from one another. The breakthrough came in 1926 when Nobel Laureate Theodor Svedberg invented an ultra-centrifuge capable of reaching a speed as high as 900,000 g. This speed was three to four times faster than most centrifuges at that time, providing sufficient forces to separate small biomolecules such as proteins, which facilitated the study of complex protein structures.

The next few decades witnessed huge progress in the development of centrifuges for isolating sub-cellular organelles like mitochondria and even enriched uranium for the atomic bomb project. Nevertheless, these centrifuges remained bulky, expensive, and were not widely available. It was not until 1962 that Eppendorf commercialized the first micro-centrifuge for benchtop use. Since then, materials like lightweight titanium have replaced bulky steel to provide even stronger centrifugal forces. Modern-day centrifuges also offer sophisticated features such as temperature control, user-programmed acceleration/deceleration rates, automatic imbalance detection, and noise reduction.

Micro-pipettes

A micro-pipette is a spring-loaded piston fitted with a disposable plastic tip for transferring precise volumes of liquid. Through an air buffer, the piston is separated from the liquid, which minimizes biological contamination. The modern-day micro-pipette is also fitted with a second spring that can be activated by applying stronger pressure to dislodge the pipette tip automatically.

The first glass pipette was invented by the French scientist Louis Pasteur (do you recall Pasteur pipettes

that you used in chemistry labs?), to prevent cross-contamination of samples. Following rapid developments in plastic technology, plastic pipettes were eventually developed in the 1940s.

In 1957, Heinrich Schnitger, then a postdoc in the University of Marburg, Germany, was frustrated with having to continually make and calibrate new glass pipettes to suck precise volumes of analytes for his experiments. He channeled his frustration into positive output by developing the first prototype of the modern-day micro-pipette with spring-loaded piston and refillable liquid plastic tips that he also patented in the same year. Although Schnitger's design made pipetting easier and safer, it did not offer researchers the flexibility of adjustable volume. After consulting multiple users, Warren Gilson and Henry Lardy, who were then that the University of Wisconsin-Madison, incorporated the feature of flexible volumes into the micro-pipette.

Since then, multiple features such as rubber grip and lock have been introduced to improve the ergonomics and precision of micro-pipettes. A variety of new products such as the multi-channel micro-pipette for handling large sample numbers has also entered the market. Companies have even color-coded micro-pipettes with their corresponding pipette tips to make changing pipette tips more convenient and intuitive for users.

Cell culture flasks

Cell culture flasks come in different sizes ranging from surface areas of 25 cm^2 to 225 cm^2. Therefore, they are commonly referred to as Tx flasks with x corresponding to their respective surface area. Cell culture flasks can be used to grow a variety of cells including immortalized cell lines and even primary cells from patients.

Traditionally, cells were being cultured in glass flasks. However, most cells have difficulty attaching to glass surfaces and consequently, glass flasks have to be specially treated with expensive proteins such as collagen to induce cell attachment. Even then, with batch-to-batch variability in protein quality, protein coating may not be uniform, causing uneven cell attachment. More importantly, the process of cleaning glass may also leave behind toxic detergent residues that can affect biological interpretations.

The development of disposable plastic cell culture flasks was catalyzed by a progress in plastic technology. By the 1960s, polystyrene, a type of plastic, was being tested to manufacture cell culture flasks. This plastic is transparent, easily moldable into different sizes and shapes, and can be sterilized by irradiation, making it an ideal material. Unfortunately, polystyrene is also a hydrophobic plastic, which means that it repels water and cells do not attach well to it.

It wasn't before long scientists figured out a way to modify the hydrophobic surface of polystyrene to a hydrophilic (water-loving) one. Using high energy plasma that produces reactive oxygen ions, oxygen can be incorporated into polystyrene, making it hydrophilic and cell attachment-friendly.

Starting from the 1970s, disposable plastic cell culture flasks became a mainstay in labs. The modern-day flask is also fitted with a filtered cap at its opening to regulate the flow of gases and to prevent biological contaminants from entering the flask. Evolving with biomedical needs, cell culture flasks with different surfaces have also been commercialized. For instance, Corning introduced the Ultra-Wet® Synthetic Surfaces that resemble 3D fiber-like topography that cells would experience *in vivo*. This is useful for culturing stem cells that differentiate differently in a 2D versus 3D environment. With increasing popularity in organoid (3D tissue-like structures with different cell types originating from stem cells) research, Thermo Fisher Scientific also commercialized the Nunclon™ Sphera™ flasks that have ultra-low attachment to avoid uncontrolled stem cell attachment and spontaneous differentiation.

Hemocytometers

The word "hemocytometer" means blood cell counter and its invention was linked to the popularity of hematology in the mid-1700s and optical microscope in the 1850s. A standard hemocytometer comes with a counting chamber with four squares, each measuring 1 mm^2, that is etched into the surface of glass. A specific volume of liquid, usually 10 µL, is added to the counting chamber and cell density can be determined with the following formula:

$$\text{Cell density (per mL)} = \frac{\text{Total number of cells in the 4 squares}}{4} * 1000$$

The humble hemocytometer has experienced substantial design evolution. The initial idea was first conceived by Louis-Charles Malassez, who in 1874, used a capillary tube to transfer fixed volumes of cell suspension into a glass slide with grids. Nevertheless, it remained challenging to reproducibly count cells as sample uniformity was poor with this technique. Over the next 30 years, multiple innovative features were being incorporated into hemocytometers including counting chambers with fixed volumes so that cell concentration could be back calculated. Finally, in 1913, Karl Bürker invented the closest version of the modern-day hemocytometer that exploited capillary action to draw fixed liquid volumes into counting chambers. His hemocytometer design also had two sides that facilitated duplicate counting, which subsequent designs followed.

Future trends

Factors such as user preferences, experimental needs, and plastic technology have dramatically influenced the designs of many lab consumables and equipment, but this evolution is nowhere near completion. Automation, including the introduction of robots in labs, has dramatically impacted the designs of lab equipment. Labs, especially those working in high throughput screening, are increasingly relying on robots to perform pipetting. Robotically-controlled pipetting (also known as liquid handling robots) can significantly reduce human labor, translating to cost savings. Automated cell counters, which perform counting much faster than a human, are also replacing traditional hemocytometers. Automated systems supported by rigorous check and control algorithms are expected to become widely used. Researchers can also look forward to future designs with wireless systems for remote control.

Lab supplies and equipment are also undergoing the miniaturization revolution to become more price-friendly for democratizing scientific research. One great example is the evolution of cheaper benchtop centrifuges from bulky, expensive floor model centrifuges. Some research groups have taken the idea of "miniaturization" and "cost-savings" even further by adapting unconventional materials as lab supplies. For instance, the Whitesides group at Harvard University has created handheld centrifuges modified from an egg-beater to separate blood cells. The same group has even creatively used bubble wraps to store and transport liquid samples for analytical assays. Similarly, the Prakash Lab at Stanford University pioneered a low-cost paper-based microscope with up to 140x magnification and 2 μm resolution.

University College London, the largest university in the United Kingdom, recently announced that it plans to phase out single-use plastics including lab consumables like pipette tips and cell culture flasks within the next five years. One way to achieve this ambitious goal is to look into alterative materials. It may not be surprising that reusable materials and equipment with low carbon footprints like handheld centrifuges may be used even in well-funded and established labs. Interestingly, similar to the fashion industry, the design of lab supplies may be going "retro" with greater environmental objections regarding single-use plastic. Glass, an old friend of biological experiments, may regain its long-lost popularity.

The design of lab supplies and equipment is continually undergoing creative reinventions. Beyond considering users' preferences, manufacturers should anticipate factors such as environmental considerations and institutional research policies that could influence how they design and manufacture lab supplies. It will be an exciting time ahead.

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Finding Quality Pre-Owned HPLC is Possible

USED HPLC SYSTEMS ARE AN AFFORDABLE OPTION, BUT IT IS IMPORTANT TO CONSIDER COMPATIBILITY, CONDITION, AND SUPPORT **by Michelle Dotzert, PhD**

HPLC is a powerful tool for analytical chemistry that enables separation, identification, and quantification of compounds present in a sample. It is suited to a wide range of applications including pharmaceutical research, food science, environmental, and forensic applications, among many others. The ongoing evolution of HPLC has led to greater speed, sensitivity, and efficiency; however, these improvements come at a substantial cost. Laboratories looking for more affordable options, especially startup labs with limited funds, should consider purchasing pre-owned HPLC systems.

There are a few important factors to consider to ensure the best pre-owned option for the lab, such as compatibility. "If you plan to pair an HPLC with an existing mass spectrometer, confirm compatibility and any firmware requirements beforehand," says Ceylan Bilgin, director of marketing at International Equipment Trading Ltd. (IET).

It is also essential to work with a reputable reseller who will ensure equipment has been properly tested, as well as provide a warranty or guarantee with purchase. Following testing, "we sell our equipment guaranteed to meet or exceed original manufacturer's specifications," explains Bilgin. It is also worth inquiring about installation and networking services for a more efficient setup and to ensure appropriate configuration. "If the HPLC is purchased in conjunction with a mass spectrometer, we include installation and networking of the LC components with the mass spectrometer," says Bilgin.

Wondering if the column, the critical component of an HPLC system, can be purchased used? "Yes," says Bilgin, "we have a limited number of columns available that we test with the HPLC prior to shipment. The customer should inquire regarding testing that was done and whether or not those columns meet their application needs." Other components, such as tubing and consumables should always be purchased new as they are easily contaminated.

As for software, there are many options including original equipment manufacturer (OEM) and third-party programs. A third-party option may be appealing, however opting for OEM software can prevent some challenges in the future. "We recommend the OEM software for HPLC systems," says Bilgin. "In the event that you have an issue that needs to be addressed, tech support may not be familiar with third-party software programs."

The main advantage of purchasing used HPLC systems is the lower price, but in some circumstances, it is not advisable to purchase pre-owned. "If you require a specific configuration that is not available in the used market, it would be better to purchase new," says Bilgin. "If you are purchasing the HPLC for a specific application and you are not sure if that configuration will meet your needs, you should confirm this with the original manufacturer's technical support department," she adds.

Pre-owned HPLC systems are a more affordable alternative to purchasing new; however, given their high degree of sophistication, it is essential to work with a reputable reseller, and ensure appropriate testing has been completed. With some additional research, including warranty and software options, as well as technical support and installation services, a used HPLC system can be a valuable addition to many labs.

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Succession Planning in a Lab: What, Why, Who, and How

A SOLID STRATEGY CAN SAVE YOU TIME AND RESOURCES **by Olena Shynkaruk, PhD**

When I think of succession planning, the first situation that comes to mind is the boardroom of a multinational company, filled with executives and investors trying to find a replacement for the CEO who announced their retirement. However, succession planning can relate and benefit not only global businesses but also improve lab operations. As a lab manager, you are responsible for the day-to-day operations and management of lab resources, while talent management might not be something that was included in your former training. This article intends to help you navigate the process of succession planning and facilitate you and your coworkers' career transitions and retirements. Whether you are a lab manager of an academic, industry, or start-up lab, succession planning is worth paying attention to as it can provide a valuable strategy for talent management and save you and your organization time and resources in the future.

What. Succession planning, or rather *succession development* is a proactive process of identifying key leadership and technical positions and shifting your employees to the right positions at the right time upon organizational changes like career transitions and retirement. Succession development in a lab is a multilevel process. It corresponds to identifying and training successors for not only senior positions in a lab but rather for every position: from lab technician to research associate, principal scientist, and lab manager. It helps continuously align employees' talents with core values of your lab, maintain its strengths, and address its weaknesses.

A succession plan is not a replacement plan. It's an active process of development (hence the term succession development) of your employees. It requires not only a document (e.g. an actual plan), but also an active program that includes skills development, follow-ups, improvements, and supporting funding. The program requires objective and performance metrics. The scale of succession development depends on the size of your lab and affiliated organization.

> "Ninety-four percent of employers surveyed report that having a succession plan positively impacts their employees' engagement levels."

In its turn, a replacement plan is rather a reactive process, where the position is filled when it becomes available. It doesn't matter as much if it would be an external or internal hire. However, it comes at the price of not only external search but also current lab members' engagement and morale—more on this in the following Why section.

Why. So, Why do we bother with succession planning in a lab? There are numerous benefits, with some being obvious (like uninterrupted lab operation) and others somewhat surprising (promotion of collaborative culture).

Uninterrupted lab operation. Having no technician to operate an instrument may result in the work overload for a lab manager and other lab members, slower results turnover, and loss of research advantage. Having a succession development program in place would allow an uninterrupted workflow and happier co-workers.

> "As a lab manager, your unique perspective and insights into succession planning (e.g., lab members' skills, engagement, and productivity) improves the odds of the plan being successful."

Coworker engagement. According to the Hireology team, "ninety-four percent of employers surveyed report that having a succession plan positively impacts their employees' engagement levels." What would increased engagement provide? Positive workplace culture, increased effectiveness, and longer workforce retention, to name a few.

Collaborative culture. Having a proactive succession development program in place designed around leadership training and skills development in a group and individual settings would promote cross-functional collaborations and foster meaningful connections in your lab.

Who. The million-dollar question in succession planning is, "Who is responsible for it? Is it a CEO? Team of senior executives? Professor? Or a lab manager?" We broke down the answers relative to the common types of workplace.

Academic lab. As you probably know, the position of a lab manager in academia is fluid. For example, in the academic setting, anyone from a research associate to a postdoctoral fellow can hold the title of a lab manager. The primary role of a lab manager is to support lab members in their work and ensure smooth operations of the lab. Identifying key lab positions and projects is usually done by a professor. Therefore, it would be safe to assume that it is a professor who usually develops a succession plan. However, "the lab manager can provide staff suggestions, conduct candidate reviews, and assist during the interview process," says Yan Li, financial and administrative coordinator, lab manager of professor Robert Campbell's lab at the University of Alberta. This assistance to upper management (a.k.a professor) is incredibly valuable for the development of an effective succession plan.

Industry lab. In industry, C-suite executives are typically responsible for the development of a succession plan. And although there might be more regulations around lab management in an industry lab compared to an academic lab, the role of a manager to maintain the morale of the lab and assist upper management in succession development is similar to an academic lab. The lab manager is the on-the-floor operator and record keeper. As a lab manager, your unique perspective and insights into succession planning (e.g., lab members' skills, engagement, and productivity) improves the odds of the plan being successful.

Start-up lab. In a start-up environment, a succession plan might need to adopt an agile form, similar to the business model itself. There might not be years of operations to develop and perfect the process. These days, the high mobility of the workforce, especially in the tech industry, requires high agility of the succession plan. Therefore, creating a collection of protocols and operating procedures, as well as training your team to be able to fill in for each other's positions, or at least be aware of each other's project progress, might be a good start.

How. Depending on the organization, there are multiple ways to approach succession development. Below, there are five ways that can be used immediately.

Plan long-term. Successful succession development is a long-term process spanning years. It has objectives and performance measures to provide a valid framework for continuous improvement. In a service lab, it might look like each member learns how to operate and troubleshoot every piece of equipment. Meanwhile, suitable candidates have professional and leadership development opportunities. Making the candidates aware of the succession development process will deepen their engagement, although one needs to be careful not to alienate other lab members.

Identify skills. Succession planning is not only identifying your successor, but also making sure each employee is using their best skills to the best of their abilities. This might require identifying if your lab members have any skills gaps and bridging them. This process can be done using software. For example, Plum software harnesses the power of artificial intelligence and psychology to identify your employees' talents and help you make position decisions.

Establish short-term goals. Having short-term goals like quarterly professional development reviews and conversations around each lab member's career goals will facilitate the development of the succession plan. It will also help anticipate and analyze potential forthcoming transitions and changes. Asking your lab members about their career goals will help you to know what people actually want in their careers. For example, not all employees strive for management positions. It's a great opportunity to check in and see where things are at.

Account for future roles. With the rapid development of technology, including process automation and artificial intelligence, your lab day-to-day operations might change within a few years. This change means that roles and positions might evolve and merge. That is why a continuous review of the succession plan, its performance metrics, and analysis of what the lab will look like in two to three years will keep the succession plan relevant at the time of change.

Have a hiring policy. Having an external versus internal hiring policy is also a part of succession development. Internal hiring policy will create career growth paths for current lab members and deepen their engagement. A good rule of thumb might be having <15 percent of external hires to continue bringing fresh ideas to your workplace.

Succession planning is a proactive long-term process of securing your lab's competitive advantage and success. The best thing about it? It is never too late to start succession planning. If you are not sure where to begin, raising this question with upper management will show your engagement and care for the long-term success of the organization and create meaningful career paths and connections within your lab.

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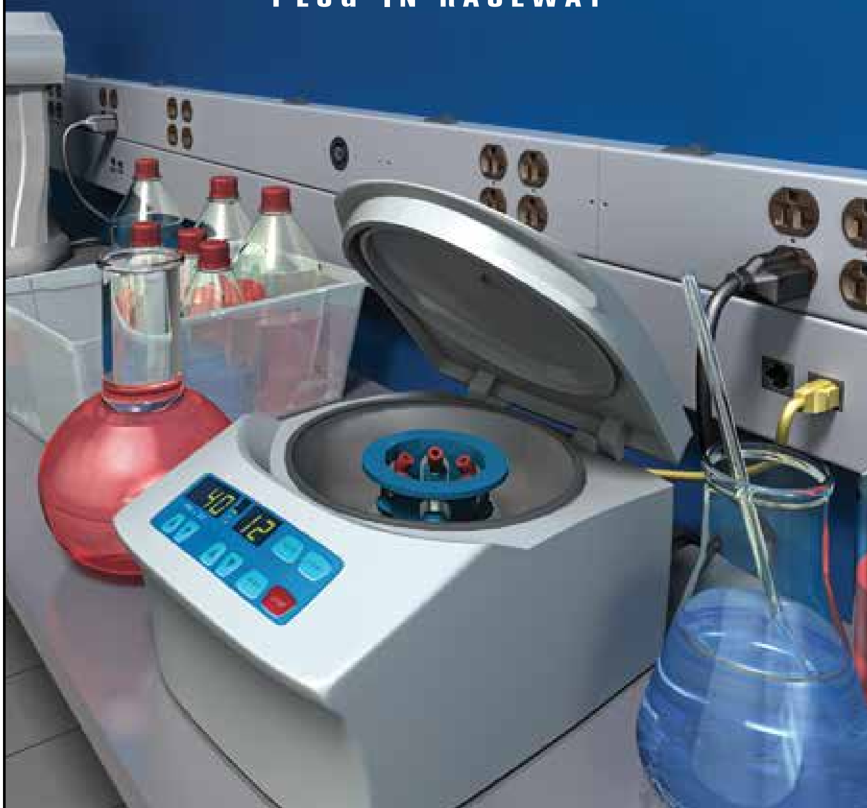

▲UCLA Health Center's mobile surgical instrument lab is housed in a Winnebago RV. *Credit: Winnebago Industries, Inc.*

Research on the Move

MOBILE LABS OFFER CERTAIN ADVANTAGES OVER BRICK-AND-MORTAR FACILITIES

by MaryBeth DiDonna

A permanent, brick-and-mortar facility is the most common type of lab, but there are certain situations where a mobile lab may prove more useful in bringing resources and testing facilities to a specific location. Mobile labs can be found in cars and trucks, recreational vehicles, ships, aircraft, and more, presenting flexible options to researchers, students, and medical personnel. One of the main advantages of a mobile laboratory is its portability—a mobile lab can be transported miles away from its home base, meaning that it can serve a broader clientele or access a wider range of research materials. A mobile lab with sleeping quarters means that money doesn't need to be spent on lodging. Testing and research that occurs on-site can often produce faster results, and reduce turnaround time for data. Mobile labs also offer a sense of community outreach, by bringing their services directly to those in need.

> "Switching from a third-party contractor to its own mobile lab will save nearly $750,000 per year."

A larger window for research

Ever wonder how a bird can fly hundreds of miles with no problem, but a human may feel exhausted after running for just 30 minutes? Auburn University has developed a mobile mitochondria lab, which enables researchers to study bioenergetics—the study of the transformation of energy in living organisms—to answer questions just like these. Auburn scientists are traveling the country in a specially outfitted RV, dubbed the "MitoMobile," in order to observe the difference in energy sources among humans and certain animals, and to examine what kind of role mitochondria plays in this process.

In order to study mitochondria, fresh, live tissue must be utilized. Therefore, researchers only have about a two-hour window to work with the material. The mobile lab allows researchers to travel to different locations to collect and study specimens on-site, which means that they are not limited to areas within a short distance of the permanent labs back at the university's campus in Alabama.

Choosing the type of vehicle to house the MitoMobile was a task for engineers in Auburn's Department of Electrical and Computer Engineering. The project team looked at other mobile labs around the country for inspiration, but could not find anything specifically dedicated to mobile mitochondrial research. "If you're using centrifuges and scales, you have to have a balanced system," says Bruce Gladden, professor of kinesiology and director of the Muscle Physiology Lab at Auburn University. "Initially, the engineers talked about things like an emergency vehicle or an ambulance, but they did the searching and discovered an RV that required the least amount of renovation inside and had most of the power characteristics needed."

"The other pro about getting an RV over some other vehicle is that it provided sleeping accommodations,"

1. Wet lab and galley facilities onboard the R/V *Shearwater*. *Credit: All American Marine* **2.** Auburn University's Mito-Mobile enables researchers to study fresh, live tissue. *Credit: Amanda Gordon* **3.** Students at work inside the MitoMobile. *Credit: Geoff Hill*

adds Andreas Kavazis, professor and director of the Muscle Biochemistry Lab, School of Kinesiology. He says that sleeping access for four to six people, along with a bathroom with a shower, means that the MitoMobile's staff can stay on the road for up to two weeks at a time. This presents an advantage over a brick-and-mortar lab because it cuts down on travel time, hotel expenses, and the lag time that occurs when traveling between sample sites and testing sites.

The testing equipment runs off a generator—solar power was considered, say Gladden and Kavazis, but the weight of the solar panels would be too much for the MitoMobile. The RV is equipped with refrigerators and freezers, along with liquid nitrogen, the setup of which had to meet safety and Department of Transportation standards. The work was done in-house at Auburn, with a project team consisting of physiologists, biochemists, chemists, engineers, and others working together to outfit the mobile lab. "I don't think we can emphasize enough the importance of the collaboration," says Gladden, adding that the engineers handled the carpentry tasks and bolted down the equipment so it wouldn't move during transport. Gladden says that his team told them about the equipment that would be needed, "what power are they going to need, what space do they need to take up, and then they went from there."

Bringing care to the client

Winnebago Industries, Inc. recently partnered with University of California at Los Angeles (UCLA) Health Center to develop the nation's first all-electric mobile surgical instrument lab. This mobile medical unit will transport surgical suite instruments between UCLA's Ronald Reagan and Santa Monica medical center campuses—cleaning, repairing, disinfecting, and sterilizing them along the way. The institution estimates that switching from a third-party contractor to its own mobile lab will save nearly $750,000 per year.

"One of the questions [Winnebago] has been working on for the past 50 years, really, is, 'What are other uses of RVs that we can build where we can take the platform of an RV or use the RV structure as a base, and build out different applications?'" says Ashis N. Bhattacharya, vice president of business development, specialty vehicles and advanced technology, for Winnebago. "There are two broad areas that we have been concentrating on—one is mobile applications of any kind, [and] a great majority of those applications have been mobile medical." He notes that Winnebagos are already equipped with complex subsystems ranging from refrigerators and freezers, to air conditioning systems, flat-screen TVs, solar panels, and backup power and generators, therefore mobile medical is a good area in which to integrate these systems. Other ventures undertaken by the company for other medical institutions include a lung cancer screening vehicle and an opioid outreach vehicle.

"UCLA is, of course, one of the nation's most well-known medical systems," says Bhattacharya, adding that UCLA Health Center's fleet also encompasses a Mobile Stroke Unit, a Mobile Eye Clinic, and a Mobile Clinic Project for people who would not otherwise have access to health care. "When we are talking about a vehicle, that initial needs analysis and design is a really critical part of the process." He describes how operating conditions and the type, weight, and power requirements of the equipment factored into the design of the mobile laboratory. Winnebago worked with Motiv Power Systems to provide an EPIC F-53 33-foot electric chassis. They also collaborated with upfitters company Summit Bodyworks to do the fit-out of the van and to put the lab equipment in place—this includes two desks housed in a slide-out area, two workbenches, and an industrial sink, along with two stations for 5.5 gallon ultrasonic cleaners. Custom cabinetry and equipment can also be found inside.

The UCLA vehicle is an all-electric, zero-emission vehicle, which means that the RV does not need to idle while performing the instrument sterilization. Not only is this better for the environment, but it allows the vehicle to service areas that may have local anti-idling laws. The battery charge is expected to last eight hours.

"You can take services to the customer, versus having the customer come to you. One of the phrases I recently heard was, 'The patient will see you now,'" says Bhattacharya. "This is a general trend that I think is of interest for readers of laboratory reports … whether it is for demonstrating new technologies, for doing on-site testing, for capacity utilization of expensive pieces of equipment. If you have a million dollars' worth of equipment on the vehicle, you can really ensure that the vehicle is used for many hours of the day versus staying idle. So, capacity utilization is a key thing."

Research and a classroom at sea

Duke University's Marine Lab has used a number of research vessels in recent years. After the R/V *Cape Hatteras* was retired in 2012 and the R/V *Susan Hudson* followed suit in 2014, the institute used smaller boats—the *Richard Barber* and the *Kirby-Smith*—which were only suited for short trips close to the coast. The Duke Marine Lab received a donation of $11 million in 2017 to fund a brand new, larger vessel that could better accommodate the marine lab's teaching and research capabilities. The resulting larger ship, the R/V *Shearwater*, now allows for overnight trips, and possesses the capability to perform oceanographic research rather than solely coastal research.

The R/V *Cape Hatteras* was owned by the National Science Foundation and was operated by a consortium of North Carolina universities. One of the advantages of the R/V *Shearwater*, says Katie Wood, assistant director, undergraduate & marine lab programs, Duke Marine Lab, is that the Duke Marine Lab could fully make it their own. "Since this vessel is owned by us, which is different than the *Hatteras*, we were able to customize it more to what the Marine Lab courses and research needed to be," she says, noting that the *Cape Hatteras* was a "regional" vessel that needed to be shared between several institutions.

The *Shearwater*, designed by Teknicraft Design, was manufactured at All American Marine's production facility in Bellingham, Washington. JMS Naval Architects provided assistance to Duke Marine Lab in regards to identifying the vessel capabilities and specific oceanographic outfitting; JMS also served as the vessel owner's technical representative during the construction, outfitting, system tests, and sea trials at All American Marine.

The R/V *Shearwater* houses a combined total of 84 square feet for both dry and wet labs; the vessel features a wet wall with a debubbler and large sink, and ample, easily accessible rack space in the dry lab. There are also various kinds of research instruments and equipment, a navigation deck, a diving platform, teaching spaces, and sleeping quarters with bunk beds for overnight outings. The boat can accommodate up to 30 people for day trips and up to 15 people for overnights. It is outfitted with an A-frame and winches, used for the deployment and recovery of instrumentation; a crane, used for loading and discharging the vessel; and a 16-foot auxiliary boat. A track system is used to tie in any equipment needed during testing, and there is a built-in temporary opening provided for cords to access the back decks. The vessel also features a dedicated scientific wireway throughout for temporary wires.

"When we first started talking about getting the vessel and what that would look like, we certainly spent a lot of time talking about different research faculty, figuring out what the different needs were for the mammal team versus the biological oceanography team; to see what equipment should be standard; are there things it absolutely needs to have now, anything we should have later?" says Wood.

The *Shearwater* measures 77 feet long and is made of aluminum, meaning that it is lighter than steel ships and it can also be recycled. Degradable hydraulic oil is utilized in order to mitigate any damage from leaks, and the majority of the hull lacks paint in order to reduce paint chipping and peeling into the water over long-term use. Another "greener" feature is the vessel's fuel-efficient tier 3 diesel engines, said to be the most efficient and least ecologically disruptive engines available when the ship was being designed. The vessel has a catamaran design, with two hulls instead of one—fixed aluminum hydrofoil reduces drag by allowing the boat to be lifted in the water.

The inaugural class aboard the R/V *Shearwater* set sail in January 2020, with a biological oceanography at sea class across south Florida and Dry Tortugas National Park. It is expected to reach its home at the Duke Marine Lab in South Carolina in the spring.

"There are marine science programs all over the county. There are marine biology majors all over the country," says Wood. "There are not that many marine laboratories that run a full year-round campus with undergraduates. We're only three hours away from our main campus … I do think our program is pretty special."

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Tips for Assessing Indoor Air Quality

RECOMMENDED PROTOCOL FOR REGULAR IAQ ASSESSMENT **by Vince McLeod**

Indoor air quality, known as IAQ, and more broadly indoor environmental quality, began with a few cases of tight building syndrome and mushroomed into prominence due to cases of multiple chemical sensitivity and indoor mold contamination. Now, thanks to efforts from the Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), and the US Green Building Council (USGBC), we have a robust knowledge base for dealing with these important issues.

The EPA and OSHA have extensive information and guidance about indoor air quality at their respective websites.[1,2] The information covers building systems, preventing problems, and troubleshooting with comprehensive guidance provided.

In addition, non-governmental organizations like ASHRAE and USGBC have augmented the science of indoor air quality. ASHRAE's ventilation guide is considered an invaluable IAQ resource, especially regarding office and general workspace basic parameters. The USGBC Leadership in Energy and Environmental Design (LEED) program offers guidance for designing and building the new generation of green buildings with focus on occupant health and indoor air quality.[3]

Even so, indoor air quality issues arise due to many different and common reasons. Here are a few examples:

- Poor preventive maintenance
- Broken belt on a crucial exhaust fan
- New furnishings and floor coverings
- Delivery vehicle parked near an air intake

Assessing IAQ

As the "Safety Guy," having dealt with IAQ issues for more than a couple of decades and studied the guidance documents, I have developed an air testing protocol that may help prevent many common indoor air quality issues. My recommended testing protocol is based on EPA studies and the USGBC LEED indoor air quality commissioning requirements.

It entails a survey (of the concerned area or as an overall preventive, the entire facility or building) for specific parameters and contaminants. It is performed with portable instruments, so data is available immediately in real time. It is straightforward and inexpensive, even if consultants are hired to perform the work. Most importantly, the data is compared to existing OSHA, EPA, ASHRAE, and LEED standards or other recommended guidance levels and related directly to occupational health conditions.

HVAC evaluation

This indoor air quality survey starts by taking measurements of the classic four ASHRAE comfort parameters: temperature, relative humidity, carbon dioxide, and carbon monoxide. This is most easily done using a modern handheld IAQ meter such as the TSI Q-Trak™, or equivalent, which can measure these four parameters at once.

Temperature, relative humidity, and carbon dioxide are important indicators of HVAC system performance as well as occupant comfort. ASHRAE standard 62.1-2010 recommends ranges for these criteria. If these indicators are out of range, it could mean the HVAC system is out of balance or the amount of outside air is insufficient.

Carbon dioxide depends on occupant loading and tends to increase during the workday. If accumulation or buildup is noted, first verify the proper amount of outside air, then check the supply flows and distribution in the area. ASHRAE recommends that carbon dioxide levels be kept below the ambient level plus 700 ppm. The theoretical amount of carbon dioxide in outdoor air is around 350 ppm.

Carbon monoxide is introduced from combustion sources. The OSHA permissible exposure limit is 50 ppm, a level we should never come close to inside a building or research laboratory facility. The EPA and LEED recommend an upper limit of 9 ppm or 2 ppm above the ambient level, whichever is lowest. My experience indicates that if you see levels of carbon monoxide above a few parts per million, you should seek out the source and eliminate it.

IAQ contaminant survey

After checking the ASHRAE comfort parameters, I recommend evaluating common contaminant levels, dust or particulates, and volatile chemical vapors. The amount of particulates in the air indicates HVAC system performance and filter condition when compared to outdoor levels.

Measuring particulate or dust is more involved than measuring the classic comfort parameters, but state-of-the-art instrumentation such as the TSI Dust Trak™, or equivalent, makes it easy. Dust is usually measured in milligrams per cubic meter of air (mg/M^3) and reported for a specific particle size, median diameter of 10 microns or less and designated PM10. Like carbon dioxide, dust levels are compared to both OSHA permissible exposure limits and LEED recommended criteria. For acceptable indoor air quality, we should never approach the OSHA PEL, which is 10 mg/M^3). The amount recommended by LEED standards is 0.05 mg/M^3). Typical ambient levels with normal activity are about half the LEED standard and indoor office spaces will usually be in the microgram per cubic meter range.

To evaluate the levels of volatile organic compounds (VOCs), handheld instrumentation is also used. My favorite, the RAE Systems ppbRAE™, is a non-discriminating photoionization detector that measures hundreds of common VOCs and provides a "total" VOC reading in either parts per million or parts per billion in air. In typical office environments, these readings are the result of perfumes, colognes, and air fresheners. However, these sources do not compare to common commercial sources such as paints, adhesives, thinners, strippers, and lubricants. And, in research settings, there may be a multitude of chemicals in use. Therefore, VOC levels are very important given the many potential sources and serious health and safety consequences. The recommended level under LEED is less than 500 ug/M^3). For comparison, I typically see background levels between 200 and 300, even in hospital and laboratory buildings.

One last contaminant to consider is formaldehyde, especially if your facility has undergone recent new construction or renovation, as formaldehyde is contained in many urea resins, insulation, plywood, particle board, adhesives, and textiles. In addition, given its use as a preservative and sterilizer, research labs should definitely include this parameter. However, real-time measurements necessitate the use of portable infrared spectrophotometers, which are expensive to buy or rent and take some expertise to operate correctly. I recommend calling an industrial hygienist that will likely use low-flow sample pumps with appropriate media with the analyses done by an accredited laboratory. For reference, the OSHA PEL is only 0.75 ppm and the LEED standard for indoor air quality is 27 ppb.

Summary

Above I presented the Safety Guy Protocol for regular IAQ assessment. I recommend performing this screening at least annually and more often if your facility has serious issues or lots of employee complaints. By surveying your indoor air quality regularly, you can find and prevent many common problems before they become serious.

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What to Expect at the Lab Design Summit

A UNIQUE OPPORTUNITY FOR LAB MANAGERS AND DESIGN EXPERTS TO LEARN AND NETWORK

Following the success of *Lab Manager's* other conferences on leadership and safety, the inaugural Lab Manager Design Summit will be held in Atlanta, GA on May 11-13, 2020. This innovative conference will feature educational presentations from the laboratory design/build industry's leading experts, along with networking opportunities and behind-the-scenes guided lab tours. Architects, engineers, construction professionals, lab planners, lab managers, and others are invited to this unique event to build lasting professional connections and gain valuable knowledge to implement in their own workplaces.

The Design Summit will address some of the most common topics faced by those who design and build laboratories, including sustainability initiatives, incorporating technology into the design/build process, forming working partnerships between the design team and the lab management team, and specialty laboratory design, including higher education labs, forensic crime labs, and cannabis research labs. An extensive Exhibit Hall will offer the opportunity to network with industry professionals as you gain the resources necessary for building or renovating your lab spaces.

The event will open on Monday, May 11, with guided tours of some of Atlanta's most prominent lab facilities. The Engineered Biosystems Building at Georgia Tech is a prime example of an interdisciplinary research facility, with advanced laboratories that focus on biomedicine and biotechnology. The Yerkes National Primate Research Center conducts essential basic science and translational research to advance scientific understanding and to improve the health and wellbeing of humans and nonhuman primates. Go behind-the-scenes at these unique labs, where their facility managers and project team leaders will discuss the strategies and challenges that went into building these labs.

The two-day educational portion of the event will feature 13 unique sessions on subjects of relevance to those who plan, design, build, renovate, and work in laboratory facilities—led by speakers from the fields of architecture, engineering, construction, lab planning, academia, and more. These sessions are certified for AIA and HSW continuing education credits through the American Institute of Architects to help conference attendees fulfill their annual license requirements. The speaker's program at the Design Summit will open on Tuesday, May 12, with a keynote presentation by Star Scott, Green Labs program coordinator at the University of Georgia. Scott will speak on the topic of "Sustainable Labs for a Sustainable Future," focusing on the environmental and social impacts of the scientific research industry. Scott will present ways that the lab design/build community can make positive contributions to the environment by using sustainable design strategies, and will offer action items that professionals can incorporate into their own efforts.

Aimée Smith of RWDI will speak on "Key Aspects of High Performing & Sustainable Laboratories." Her session will explain how lab planners can incorporate holistic design into their projects to develop spaces that are comfortable and safe for lab users. She will also discuss the importance of occupant health and wellness, energy use, and proper ventilation.

In "Rise of the Machines: Next Steps," Patrick O'Keefe of Hanbury will explain how leading life science companies are incorporating ever-advancing technology, robotics, and artificial intelligence into their research environments. He will detail ways that machine learning can save lab users time, effort, and resources, and how such technology can increase planning and operational efficiencies.

"Innovative Science with Less and the Lab Future," a presentation by Mark Paskanik of CRB, will encourage attendees to think outside the box when it comes to solving common lab design problems. His session will offer practical strategies, while emphasizing the importance of team integration and visioning. He will also detail methods that lab project team members can use to reduce overall carbon footprint and budget.

Tuesday will also mark the reveal of the winners of the Lab Design Excellence Awards. This prestigious awards program, developed by *Lab Manager*, honors and celebrates the best newly built and newly renovated labs across the globe. Outstanding lab facilities will be recognized in the categories of innovation, safety, and sustainability. The winning teams will offer presentations that detail the design strategies, challenges, and successes behind their respective buildings. A cocktail reception will follow to honor the Lab Design Excellence Awards winners, and give attendees the opportunity to mingle and network with colleagues.

The third day of the Design Summit will commence with "Agile Lab Planning for Agile Labs," offered by Regal Leftwich of SmithGroup. Leftwich will explain why and how labs should incorporate flexibility and adaptability into their plans from the very beginning of the design process, and will detail which decisions in the planning stages may have the largest effect on a project's budget. He will also discuss methods for future-proofing a facility when dealing with advances in lab equipment technology.

As cannabis research is a relatively new area of scientific study, a session entitled "Designing and Constructing a Cannabis Lab" has been added to the Design Summit program. Dr. Pritesh Kumar of PhytoSciences Consultants will follow up on a hugely successful *Lab Manager* webinar he presented in October 2019, by leading a discussion on what lab planners need to consider when producing a laboratory for cannabis research. He will discuss the benefits of repurposing an existing facility versus starting from scratch, and will also outline the equipment necessary to get a cannabis research lab up and running.

The program will also include two specialty breakout sessions. Ken Mohr, Lou Hartman, and Jinhee Lee of Crime Lab Design will present "Designing for a Forensic Crime Laboratory," offering valuable insight for those tasked with developing a forensic lab. Allen Doyle of Sustainability Visions will speak on "Operations Team Building for Energy Efficiency and Occupant Health"—this session will address the importance of assembling a quality team to deal with building improvements and upgrades in order to save money and reduce greenhouse gas emissions.

The Design Summit will conclude with a presentation by Chris Small of Hanbury, "The Partnership between Lab Manager, Architect, and Contractor." Small's session is beneficial to lab managers, lab planners, and everyone else associated with building and maintaining a laboratory facility, as he will offer techniques and strategies for establishing an appropriate working relationship between all members of a project team. He will also present communication tips, ways to balance the needs of a manager and the realities of a project budget, and effective measures of project success.

The Design Summit will address the needs and questions of all those in the laboratory design/build field, and will assist lab managers, users, and purchasing influencers who wish to partner with these professionals in order to build or renovate a laboratory facility. Take the knowledge presented by these expert speakers back to your own lab facility, where you can work with your own team to overcome challenges and head off other issues before they even start.

Biopharmaceutical Glycan Profiling

CHARACTERIZING AND PROFILING GLYCANS IS ESSENTIAL FOR SAFETY AND CONSISTENCY **by Michelle Dotzert, PhD**

The biopharmaceutical industry has harnessed the power of gene expression systems, including mammalian cells, non-mammalian cells, and transgenic animals, to produce therapeutic proteins. The United States Food and Drug Administration (FDA) has approved hundreds of therapeutic proteins, encompassing monoclonal antibodies (mAbs), fusion proteins, hormones, cytokines, and enzymes for the treatment of diseases ranging from cancer to autoimmune disease. Protein-based therapeutics may be categorized based on their pharmacological activity, such as replacing deficient proteins, augmenting specific pathways, providing a novel function, interfering with another molecule, or delivering various drugs. These proteins enable more individualized treatment strategies, as they offer a high degree of specificity. Glycosylation is a post-translational modification by which glycans (carbohydrates moieties) are attached at specific sites on the protein. Glycans are a key determinant of pharmacokinetics, solubility, stability, and immunogenicity. Biopharmaceutical manufacturers must characterize and profile glycans to ensure safety and consistency, and rely on techniques including high-performance liquid chromatography (HPLC), mass spectrometry (MS), and fluorescence-tagging.

> “Biopharmaceutical manufacturers must characterize and profile glycans to ensure safety and consistency.”

POST-TRANSLATIONAL MODIFICATIONS

Therapeutic glycoproteins make up a large portion of biotherapeutic products, and have a US market value estimated in the billions. The technology used to manufacture them, however, is not brand new. “Therapeutic protein manufacturing is a mature technology invoking several cellular hosts or ‘expression systems,’ and a variety of highly effective drugs including monoclonal antibodies and fusion proteins are currently on the market,” explains Andrew Hanneman, PhD, scientific advisor, Biologics, at Charles River.

Therapeutic glycoproteins are post-translationally modified by glycan linking at specific sites on the protein, commonly at nitrogen atoms on asparagine side chains (N-linked) or oxygen atoms on serine or threonine side chains (O-linked). The process occurs subcellularly, within the endoplasmic reticulum (ER) and Golgi apparatus. “Glycosylation is closely associated with protein folding and ‘quality control’ wherein improperly folded proteins are removed from the ER,” explains Hanneman. “Following additional enzymatic glycan trimming within the Golgi, proteins either may or may not retain glycosylation as final active proteins.”

Glycans impact a protein’s safety and immunogenicity, and biopharmaceutical manufacturers often use mammalian cell lines, including Chinese hamster ovary (CHO) cells, as expression systems to produce glycoproteins with glycosylation patterns that are less immunogenic. For example, Siltuximab, Pertuzumab, and Rituximab are FDA-approved monoclonal antibodies generated in CHO cells. Many others are produced in human cell lines, most commonly HEK293 and HT-1080 cells.

GLYCOSYLATION IS A CRITICAL QUALITY ATTRIBUTE

"Several aspects of glycosylation can profoundly impact a protein's biological function and of consequence when used therapeutically, may impact its serum half-life and safety/immunogenicity profile, making glycosylation a critical quality attribute (CQA) for many biologics," says Hanneman. "For example, the terminal sugars of Fc glycans on mAbs have been shown to be critical for the safety or efficacy of many mAbs." Glycosylation can have direct or indirect effects on therapeutic glycoprotein immunogenicity. The glycan itself may initiate an immune response, or it may alter protein structure, rendering the protein immunogenic. Consequently, biological activity may be impaired.

As a result, glycan profiling has become standard practice in many laboratories, and is often achieved using HPLC. "The exact methods applied will depend on the product development history of the molecule and other specific needs or attributes driving glycan analysis as noted during drug development including challenges with releasing glycans, the need for site-specific profiling, or related issues possibly resulting from regulatory input," explains Hanneman. He notes that reproducible methods will be essential, especially in regulated laboratory environments.

TOP-DOWN OR BOTTOM-UP?

HPLC and MS are essential for glycan profiling, and they enable different analytical approaches. The "top-down" approach is designed for determination of the intact molecular weight profile, whereas the "bottom-up" approach enables determination of much more detailed glycosylation profiles. "A full suite of top-down to bottom-up glycan analysis approaches are employed at Charles River, mostly employing HPLC in combination with MS," says Hanneman. He explains the top-down approach as "LC-MS analysis of an intact glycoprotein to directly generate a mass spectrum indicating its glycosylation status or of its subunits." This direct approach enables calculation of molecular weight differences between peaks, to identify the different types of glycan modifications. A limitation of the top-down approach is its lack of sensitivity. Alternatively, peptide mapping, the bottom-up approach, begins with glycoprotein digestion into glycosylated and non-glycosylated peptide fragments. "Peptide mapping methods are highly informative and may be used in combination with glycopeptide enrichment strategies to provide insights into site-specific glycosylation, including O-linked glycans whose site localization is more difficult than N-linked glycans which regularly appear at well-known consensus-site amino acid motifs," explains Hanneman, adding: "highly glycosylated proteins such as many enzymes may be subjected to matrix assisted laser desorption/ionization MS due to 'extreme' glycan heterogeneity." Within the bottom-up approach, glycans can be released from glycoproteins either enzymatically (for N-linked glycans) or chemically (for O-linked glycans). Released glycans can be "profiled independent from the protein, which may also provide the best opportunity for detailed structural analysis," says Hanneman.

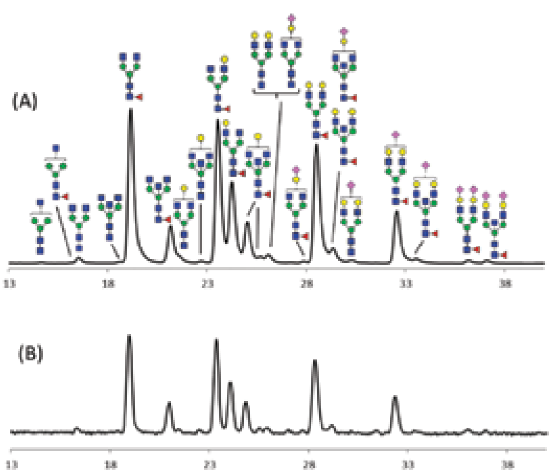

Figure 1: HILIC HPLC profiles of 2-AB labeled N-linked glycans released from human IgG A) Fluorescence chromatograph, B) Total ion current chromatogram. *Credit: Andrew Hanneman, PhD, scientific advisor, Biologics, Charles River*

ESTABLISHED TECHNIQUES ADVANCE ANALYSIS

New techniques and technologies continue to emerge, and have undoubtedly influenced glycan analysis. However, Hanneman stresses the value of a less-novel technique: "Although new approaches and technologies appear regularly, it is noteworthy that fluorescence-tagging has probably advanced therapeutic glycoprotein glycan analysis the most by enabling routine HPLC profiling without the need for mass spectrometry or related spectroscopic techniques." Unlike proteins, glycans do not absorb significant ultraviolet light, and must be labeled with a fluorescent dye for analysis with HPLC. The fluorophores

2-AA (anthranilic acid) and 2-AB (2-aminobenzamide) are widely used for glycan analysis given their stability. The HILIC HPLC profiles of 2-AB labeled N-linked glycans released from human IgG are shown in Figure 1.

Despite the benefits of fluorescence-tagging, MS is still essential for glycan profiling. "New developments in the field of sequential mass spectrometry (MSn) offer significant structural insights rivaled only by NMR (nuclear magnetic resonance)," says Hanneman. MSn enables more detailed structural analysis through re-fragmentation of product ions. Unlike tandem mass spectrometry, in which the detector consumes product ions following collision induced fragmentation, MSn enables re-fragmentation of the product ions, and can repeat this process multiple times.

GLYCANS POSE UNIQUE CHALLENGES

According to Hanneman, some inherent characteristics of glycans make them particularly challenging to analyze. "Glycans are branched structures and unlike proteins, their biosynthesis is not DNA template-driven," he explains, which makes analysis complex "if total characterization of an unknown structure is the goal." Further, glycans often have multiple structural and stereo isomers, and when combined with different linkage sites, multiple different structures are possible. "This drives the need to accept some limitations in the level of structural detail provided when using routine profiling methods," says Hanneman, "even if MS is employed, MS/MS fragmentation of branched structures might not be structurally conclusive given the high potential for isomeric structures," he explains. Developments in MSn can help to address these challenges, as multiple rounds of ion disassembly can help resolve a glycan's topology.

Fortunately, much of the challenging work has already been completed. "Most glycans from the common well-described biotherapeutic protein expression systems have already been well characterized, including the especially challenging isomeric structures," says Hanneman. "Therefore, glycan profiling now often involves smooth, quick implementation of routine profiling methods based on fluorescence-tagging, HPLC, and MS and the use of glycosidases." Some of the aspects that limit data quality and throughput have also been addressed. "Several companies provide consumables to enable rapid and confident analysis of large numbers of samples for laboratories performing cell line development, comparability, and quality control studies," he says. However, there are always exceptions, as Hanneman notes, "some aspects of sample preparation and data analysis remain non-routine, especially for the most highly-glycosylated or unusual therapeutic glycoproteins."

The therapeutic protein market shows no signs of slowing down, with thousands of recruiting and active clinical trials underway in the United States. Glycosylation impacts the serum half-life as well as the safety and immunogenicity of a therapeutic protein, and glycan profiling, tracking, and monitoring between lots is essential to ensure safe and effective drugs. Advancements in analytical instruments and techniques are overcoming the challenges of glycan characterization and profiling.

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Ken Mohr, principal at HERA laboratory planners

Jinhee Lee, CDT, associate at HERA laboratory planners

ASK THE EXPERT

ERGONOMIC LAB DESIGN

by MaryBeth DiDonna

Ken Mohr, principal at HERA laboratory planners, provides extensive experience in developing technically complex laboratory facilities for education, industry, and government. He has worked on more than nine million square feet of technology-driven dry/wet analytical/diagnostic laboratories. He has comprehensive understanding of the specialized considerations and technical issues of these facilities including process flow, operational efficiency, health and safety, security, and regulatory criteria.

Jinhee Lee, CDT, is an associate at HERA laboratory planners. Equally capable in laboratory design and planning, Jinhee believes you don't need to sacrifice form for function. Laboratories can be both beautiful and functional. Jinhee brings extensive experience in laboratory spaces for academic, R&D, forensic, and government projects. She has excellent skills in organizing and coordinating the collaborative efforts of client groups and design professionals to achieve project goals in an efficient and successful process.

Q: What is "ergonomics" in regards to lab design?

Jinhee Lee: The US National Institute of Occupational Safety and Health (NIOSH) defines ergonomics as the scientific study of people at work. Ergonomics is not simply providing good lab seating or making items reachable; it is the relentless pursuit of good design in the workplace for what people do well, and design against for what people do not do well, thereby fitting the job to the person to enhance human performance. Laboratory environments require constant repetition, intense hand-eye coordination, precise arm and hand movements, manual materials handling, and acute visual concentration. The scientists working in these high-tech labs are exposed to a multitude of ergonomic risks due to the nature of their work. Implementing Universal Design—a phrased coined by architect Ronald Mace to describe design that is accessible to all regardless of gender, age, disability, or other factors—emphases ergonomic aspects that address flexibility and provide comfort. Modern laboratory environments are focused on science, and the humans engaged in the work are sometimes forgotten. We approach lab design in a holistic way, considering workstation design to accommodate an individual's needs, lab environment response to personal comfort, acoustical control, removing barriers to increase productivity, and maximizing natural light.

> "A flexible design solution with multiple configurations and utility delivery can accommodate the scientific need while enhancing ergonomic design."

Q: What are some of the risk factors involved with improper ergonomics?

Jinhee Lee: One potential risk is reduced working memory—what we use for reasoning and guiding decision-making and behavior. Poor lighting, unnecessary noise, and distractions can hinder our ability to concentrate, a serious problem in an environment that requires intense focus. Proper design can help. A flexible design solution with multiple configurations and utility delivery can accommodate the scientific need while enhancing ergonomic design.

Another real risk is eye fatigue. We associate positive and negative feelings with colors. Color can also send a message of calm or energy. In laboratory design, black countertops are often the standard. However at least one government study has found that workers who stare at black countertops for more than four hours encounter eye fatigue resulting in reduced ability to concentrate and increased lethargy.

Q: What kind of technology do you use in ergonomic lab design?

Jinhee Lee: Good lab design that meets Universal Design meets everyone's needs. Some design solutions like wire pulls and knobs tend to snag lab coats, get bumped into, and cause injury. One way to resolve this issue is to provide a recessed pull with an angled recess for easier accessibility. Another exciting technology that is increasing rapidly is the use of robotics to perform a wide variety of mundane tasks, alleviating repeat actions such as moving trash, delivering glassware, distributing consumable supplies, and moving heavy pallets of material. A government building under design in Singapore is providing a template for how Autonomous Guided Vehicles can perform these time-consuming tasks.

Q: What is the most common complaint or request from lab users in regards to ergonomic lab design?

Ken Mohr: The most common complaints from lab users about their existing laboratory space often include a lack of knee openings, countertops set at the wrong height, noise issues, poor lighting, temperature problems, and the lack of good lab seating at the bench.

Q: What is a common misunderstanding about ergonomics in lab design?

Ken Mohr: The most common misunderstanding is that one simply applies the design guidelines following Americans with Disabilities (ADA) Act that they are addressing ergonomics. This is only a small part of good ergonomic design. The Department of Justice published revised regulations for portions of the ADA to set minimum requirements—both scoping and technical—for government facilities, public accommodations, and commercial facilities to be readily accessible to and used by individuals with disabilities. Most architects apply the design guidelines universally on doorways, regarding pull and push access for reach clearance. Depending on the client type (private, state, or federal), a review of the regulations must occur, followed by a determination of how to apply the regulations. Most regulations state that five percent of the facility needs to meet ADA requirements, or no fewer than one workstation that meets ADA regulations must be provided in each lab. Both allow an individual with a disability the opportunity to work in a lab at the bench, sink, fume hood, and instrument station. The common response to these regulations is to lower the bench height and fume hood work surface height to 34", along with the controls for services, and bring the sink and services fixtures forward within a 12" reach, which allows for wheelchair clearances under the sink.

Q: Why exactly should ergonomics be considered when designing a lab?

Ken Mohr: Considering human factors when designing a laboratory is no different than the scientific impact on the space, accommodating the right number of staff working in the laboratory, and providing the right type of infrastructure to support laboratory equipment and instrumentation. The goal is to prevent soft tissue injuries and musculoskeletal disorders caused by sudden or sustained exposure to force, vibration, repetitive motion, and awkward posture. To create an ergonomically sound work environment, NIOSH ergonomists and industrial hygienists recommend designing tasks, workspaces, controls, displays, tools, lighting, and equipment to fit each employee's physical capabilities and limitations. As design professionals in this industry, we work to create a universal environment that is generally acceptable by all while addressing the special needs of ADA.

> "The goal is to prevent soft tissue injuries and musculoskeletal disorders caused by sudden or sustained exposure to force, vibration, repetitive motion, and awkward posture."

__MaryBeth DiDonna__, lab design editor for Lab Manager, *can be reached at mdidonna@labmanager.com.*

BATHS AND CHILLERS

DESIGN DERIVES FROM BOTH CAPACITY AND UTILITY

by Brandoch Cook, PhD

Baths

The water bath is both the most ubiquitous, and sadly the most forgotten, piece of research laboratory equipment. If your laboratory space is anything like the suite I'm in, you may even still have the same holdover Precision 183 model from about 1987 backed into a corner, with the crusted asterisk of tape over the temperature dial warning potential meddlers: Do Not Touch. However, its quotidian nature and homely design bely its durability through almost constant use, and may allude to the longevity and parsimony of your principal investigator, who can pass it on when he retires, telling his favorite junior successor, "Here, take this. I've had it since before the university computerized its inventory and tagged equipment with bar codes." While indestructible and inarguably useful, these bellwethers of established laboratories can also be as frustrating as the appendix or the pinky toe. We know they are there for an evolutionary reason, but we don't notice them until neglect or abuse mark them as glaring and tragic vestiges in an otherwise sleek body.

For example, if you have assigned lab jobs to your personnel, and the water bath designee has forgotten to clean them and apply germicide, chances are high that any contamination you discover in your tissue culture reagents, or sensitive molecular biology experiments, is coming from those baths. Alternatively, if someone walks by and bumps the dial with her elbow, they may inadvertently change the temperature dramatically. Now your enzymes or your thawing vials of precious cells are cooking instead of making their contributions to science, and by the time you notice, it will take a couple of days of tinkering with the dial to get it back to exactly the right place. (Note: always keep an accurate thermometer in any bath, and check it before you put any reagents or samples in there). Conveniently, it turns out that the technology advanced to digital temperature control many years ago. Moreover, the specialized provider Lab Armor began offering bead-based baths around a decade ago, mitigating much of the maintenance and contamination worries associated with water baths. Although retail prices are higher, the cost of replacing a water bath with a bead bath is often less than the cost of lost time and reagents due to one contamination event.

Like water baths, bead baths allow temperature control of reagents and samples from ambient to 100 degrees Celsius. The switch from water to thermal, non-uniform, metallic alloy beads, however, creates an ergonomically favorable situation in which tubes, vials, and flasks can stand upright with openings and cap threads well above the surface of the heating medium, with no potential for seepage into or out of those containers. Bead baths also eliminate the need for liquid germicides, removing potentially powerful environmental and biological pollutants from their inevitable disposal and distribution through the water cycle. The dry medium obviates the risk of splash-back hazards when baths are hot, or burn hazards when heated steel reservoirs need to be dumped and refilled. Instead, beads are in principle eternal, with no need to replace or clean them other than an intermittent ethanol spray. Finally, bead baths just somehow look

cool and futuristic, even though they have inhabited the present since it was the somewhat-recent past. The near future of the technology may include the introduction of novel alloys that allow compatibility with temperatures greater than boiling, in a way that can compete with the greater scalability and temperature control of circulating baths. Correspondingly, there may be forthcoming changes in bead design to better mimic the heat transfer and bath uniformity properties of water so that the depth and volume of beads have less of an impact on discrepancies between gauge temperatures and measured temperatures.

Chillers

A chiller, in its simplest iteration, removes heat from a liquid via vapor compression or a refrigeration/absorption cycle, and circulates the chilled liquid to cool associated equipment, samples, or another effluent stream. Similar to an air conditioner, its cooling power is measured in BTUs, representing the amount of heat removed over time. Chillers are, of course, more versatile and the scale of cooling needed in the laboratory, medical, or industrial environment is a consideration unique to the experiment being done or to the equipment requiring temperature control. Chillers can be used by any biomedical laboratory to precisely specify a low temperature for a given experiment, such as optimizing DNA ligations at 16 degrees. However, their power and versatility come into better focus as temperature control modules for expensive and sensitive equipment. Such equipment includes electron microscopes and LC-MS apparatuses that exude and would otherwise trap heat in closet-sized rooms, as well as MRI, particle accelerators, and experimental lasers that function optimally within narrow temperature ranges.

Because of this wide variability in chiller applications, calculations to determine power needs are necessary to optimize solutions and obtain the right sizes and configurations. Although these calculations are relatively straightforward, when customizing chiller solutions, you should expect your product rep to be able to accurately complete them for you and develop an appropriate design solution. Therefore, chiller optimization also requires analyzing available space and how chiller configurations fit within that footprint. Additionally, this includes an assessment of whether air-cooled or water-cooled configurations are best, and whether a benchtop chiller is adequate, as they typically provide a maximum of 4000 BTUs (1/3 ton or 1051 Watts). Because air-cooled condensers release heat directly to the surrounding environment, they are generally more suitable for large laboratory spaces—confined equipment rooms therefore will normally necessitate water-cooled condensers. Customization of chillers to associated processes or equipment implies a vast potential for scalability. Accordingly, one configuration can faithfully maintain temperature control of miniscule enzymatic reactions, while another can preserve the function of production equipment in industrial facilities. For example, OptiTemp offers the generalist OTC series of air-cooled and water-cooled chillers, which can be rack-mounted in series or wheeled individually around the research space. At the other extreme, they offer the OTM series of stationary, industrial-capacity chillers, as well as custom solutions to fit both power and space requirements unique to end-user specifications.

> “Bead baths also eliminate the need for liquid germicides, removing potentially powerful environmental and biological pollutants from their inevitable disposal and distribution through the water cycle.”

The principles of function and the nature of end-user needs have driven the design of both baths and chillers. At opposing ends of temperature control, they offer scaled, precise, and affordable options for laboratory, medical, and industrial capacities.

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FOR ADDITIONAL RESOURCES ON BATHS AND CHILLERS, INCLUDING USEFUL ARTICLES AND A LIST OF MANUFACTURERS, VISIT **WWW.LABMANAGER.COM/BATHS-CHILLERS**

COLD STORAGE

ADVANCED TECHNOLOGY AND SOME SIMPLE TECHNIQUES MAKE MORE SPACE

by Mike May, PhD

When designing most any life science lab or running an existing one, scientists need cold storage. In many cases, scientists need lots of cold storage, but less can be more. It's possible to improve the efficiency of cold storage by design or renovation.

In practice, cold storage is finite. As Allison Paradise, founder and CEO of My Green Lab (San Diego, CA), says, "Ultimately, cold storage is limited by available floor space." Plus, if a lab manager does want to add more cold storage in a lab, even more than floor space matters. "It's expensive!" Paradise says of cold storage. "It's expensive in upfront costs, and it's expensive to maintain—electricity, general maintenance costs."

So, instead of thinking of it as just a freezer, realize that cold storage plays a part in a lab's entire ecosystem. "As a result of lab sustainability efforts—including the increasing number of research institutions with green lab programs—and efforts like the International Laboratory Freezer Challenge, there is growing awareness and growing action by scientists to minimize research's footprint on the planet, including being efficient with cold storage, such as purchasing energy-efficient units, [and] raising temperatures on ultra-low temperature freezers to −70 from −80 degrees Celsius," says Kathryn Ramirez-Aguilar, green labs program manager at the University of Colorado Boulder. "I have been impressed with the actions that lab members are willing to take at CU Boulder because they want to do their part in minimizing their footprint."

More from less

In addition to the footprint, other factors do matter. "From a physical perspective, it comes down to maximizing the interior useable space while limiting the exterior footprint of the equipment," says Josh Lewis, global product manager, ultra-low temperature freezers at Thermo Fisher Scientific (Asheville, NC). "This optimization has been a key design consideration in recent years, especially in ultra-low devices where vacuum insulation panels have increased interior volumes by reducing the necessary insulation thickness of the cabinet walls."

How scientists store samples also impacts the available freezer space. "In an individual unit, one can make more space by using high density-storage formats or storing samples in appropriately-sized containers," Paradise explains. "For example, don't use a 50-milliliter conical tube when a 15-milliliter tube will do." She adds that scientists can also make more room in a cold storage unit by "maintaining the unit properly to avoid ice buildup and discarding old samples when they aren't needed any more."

To keep the samples in cold storage under control, some standard procedures really help. "Implementing an inventorying system works best for a lab and enables the lab to have good knowledge of what items are in its cold storage units and where they are located," Ramirez-Aguilar says. "This makes it easier to purge samples that are no longer needed, thus making it easier to make more space for new samples within existing units."

Top tips

For top efficiency, a research institution can develop a core of cold storage units run by a manager, and allow scientists to rent space. "This not only would provide lab members with support for good sample management, it also keeps labs from having to use their individual lab space for cold storage units," Ramirez-Aguilar explains.

The space that can be used for cold storage also depends on energy efficiency. "The more units there are in a room, the more heat that gets rejected into the room, which drives up the HVAC bill," Lewis explains. For example, he points out that using a variable speed system can reduce energy consumption "by more than 50 percent and reduce the heat rejected to the room by the same amount."

Where possible, scientists and research institutions should design efficient cold storage into a facility. That headstart creates the best outcome.

Mike May is a freelance writer and editor living in Texas. You can reach him at mike@techtyper.com.

FOR ADDITIONAL RESOURCES ON COLD STORAGE, INCLUDING USEFUL ARTICLES AND A LIST OF MANUFACTURERS, VISIT **WWW.LABMANAGER.COM/COLD-STORAGE**

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GLASSWARE WASHERS

BEYOND CLEANING WITH ULTRASOUND

by Mike May, PhD

Many scientists use an ultrasonic cleaner to remove grunge from glassware and more. This method uses high-frequency waves to create fast-growing bubbles that burst in contact with a surface, and that causes cleaning.

"Customers purchase ultrasonic cleaners for a variety of reasons," says David Hayes, global product manager at Cole-Parmer (Vernon Hills, IL). "They are used in a wide variety of industries and applications." Typical samples include hard metals, ceramics, glass, and plastic. "Almost any non-porous item that can normally be immersed in water can be cleaned," adds Hayes.

In a lab, an ultrasonic cleaner is commonly used for "cleaning labware and glassware by removing dirt and grime, which would normally require tedious manual cleaning," Hayes explains. Many companies make these devices, and they come in a wide range of models. When asked what features of an ultrasonic cleaner are the most important, Hayes provides a list:

- Degas mode for improved cleaning efficiency and easy sample preparation
- Multiple power settings that handle normal or delicate cleaning
- Controls for temperature, surface tension, viscosity, and density of the liquid
- Sturdy rubber feet that prevent movement during use
- Leakproof housing
- For larger size units (6 liters or more), external drains are ideal for easy replenishment of cleaning solutions
- Perforated or mesh trays to suspend items to prevent transducer damage

When designing a new lab or renovating one, look for the features in an ultrasonic cleaner that best complement the work done in the lab. To expand the applications of a single ultrasonic cleaner, also consider the accessories, such as trays of various sizes, shapes, and designs. As noted in an example below, the fluid used in an ultrasonic cleaner also impacts its efficacy.

Unexpected applications

Ultrasonic cleaners are suited to an extensive range of applications other than cleaning. "Ultrasonic cleaners are also used for cell separation, sample preparation, and degassing of liquids, such as degassing of HPLC solvents, emulsifying, and dispersing," Hayes says.

Then, some even more unexpected applications arise. As an example, scientists in India used an ultrasonic cleaner in making a barium stannate-graphitic carbon nitride nanocomposite (BSO-gCN). The scientists noted that the material developed with this method "could be a potential candidate for electrochemical sensor applications."

In China, scientists used an ultrasonic cleaner set at various frequencies—28, 45, and 100 kilohertz—in preparing a food called peanut sprout, which contains resveratrol. Some studies connect this polyphenol with a range of potential health benefits, including antioxidant and antitumor activity. The team of scientists in China concluded "ultrasound treatment combined with germination can be an effective method for producing enriched-resveratrol and poor allergic protein peanut sprout as a functional vegetable."

Beyond preparing peanut-based foods, an ultrasonic cleaner also has applications in pathology. In Japan, scientists filled an ultrasonic cleaner with a decalcification fluid and used it to prepare hard tissues, such as bones, for histopathology. They noted the procedure was effective for decalcifying hard tissue with minimal damage.

From peanut processing and pathology to sensor studies and more, ultrasonic cleaners go far beyond cleaning. That said, these platforms should not be underestimated for cleaning capabilities—uses that are required in basic and industrial research, as well as health care applications, such as cleaning surgical instruments. So, think of ways to shake up the research in a lab. It might trigger more than cleaner beakers.

***Mike May** is a freelance writer and editor living in Texas. You can reach him at mike@techtyper.com.*

FOR ADDITIONAL RESOURCES ON GLASSWARE WASHERS, INCLUDING USEFUL ARTICLES AND A LIST OF MANUFACTURERS, VISIT WWW.LABMANAGER.COM/GLASSWARE-WASHERS

QUICK TIPS FROM LINDA

FLEXIBLE LAB SPACES

DID YOU KNOW:

A major design trend when constructing new labs or renovating existing ones focuses on creating flexible, customizable spaces.

Many tools enable researchers to do their best work—in that same vein, the space itself is a tool to enable research. Looking beyond specific tasks can help a team avoid designing rigid environments that would lock in task-oriented operations and lock out modifications to meet the changing needs of researchers. Designing for flexibility creates a space that can evolve as the research activities and the tools to execute those activities evolve. As important, flexibility in the lab fosters creativity, giving freedom to explore new questions with the right tools.

In addition to the day-to-day flexibility and functionality of individual spaces, the adaptability of the building over its life cycle is crucial. As new equipment, technology, and work styles enter the profession, adaptable spaces can undergo minor renovation to facilitate change. Future functionality allows spaces to go beyond the efficiency of multi-functional spaces in the present.

FOR MORE INFORMATION, VISIT:
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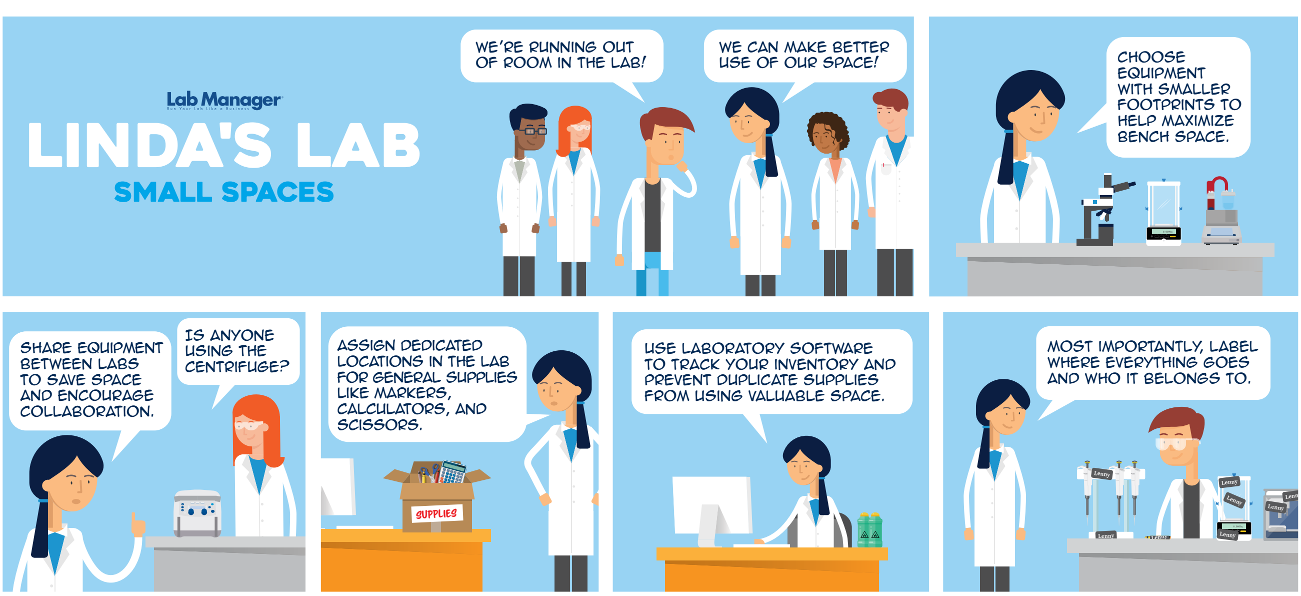

MICROWAVE DIGESTION

METHODS TO ACHIEVE CONSISTENCY

by Angelo DePalma, PhD

Chemists of a certain age remember their first experience with microwave chemistry either nostalgically, whimsically, or in my case, with a certain sense of dread. Drying several grams of magnesium sulfate in the same microwave oven my fellow group members used to reheat coffee did not go over well. The chemical was not particularly toxic but its splatter took the better part of a morning to remove. Subsequent comments about food and beverages tasting "a bit like magnesium..." did not help intra-group relations.

Microwave digestion works by exciting nearby water molecules to tear sample materials apart. Adding strong acids, or even a base, speeds up sample homogenization. What results is a mixture of organic materials at various stages of decomposition, and highly solubilized metal ions with uniform oxidation states suitable for analysis by inductively coupled plasma, atomic absorption, or atomic emission spectroscopy.

Scientists prefer microwaves because competing methods all have serious drawbacks. For example, ashing—where samples are burnt until only ash remains—is prone to analyte loss due to incomplete combustion. Fusion decomposition, a high-temperature technique that uses salt fluxes to solubilize samples, is labor intensive and suffers from interferences from fusion agents.

Microwave digestion solubilizes a broad variety of samples relevant to many industries, including agriculture/foods, clinical/life sciences, environmental, geoscience and mining, metallurgy, pharmaceuticals/nutraceuticals, paints and coatings, plastics, and polymers. "The only materials that would not be appropriate for microwave digestion are those that oxidize violently when acids are added," says Leanne Anderson, technical marketing manager at CEM (Matthews, NC). "For example, explosives, propellants, and perchlorates."

Acid selection is probably the most important factor in microwave digestion, according to Anderson. "Digesting in a closed vessel allows heating the acid above its boiling point. This increase in temperature dramatically increases the oxidation potential of the acid, allowing the use of safer acids; for example, nitric acid instead of perchloric."

Nitric acid is most commonly employed for organic samples, including plant and animal tissues, oils, polymers, and pharmaceuticals. Sulfuric acid may be required to break up aromatic hydrocarbons. Anderson recommends that organic samples be pre-digested up to 15 minutes. Pre-digestion involves adding acid to the sample but leaving the vessel uncapped, in the fume hood, so that if the sample is prone to produce a lot of of gas it can discharge this gas before the vessel is sealed.

Anderson notes, "Inorganic samples do not contain much carbon, so they do not usually produce high pressures in digestion, though they may require higher temperatures than organic samples."

Power and time

When microwave digestion was first introduced, control over process parameters was limited to time and power. Anderson draws the analogy to microwaving a frozen burrito: "You can program the amount of time and the power levels but you don't know if the center is cooked or still frozen until you cut into it." This was a problem for early microwave reactors, too, which led to the development of temperature-controlled units that have become the standard for digestion today.

By utilizing either contactless or *in situ* temperature measurements, the digester applies the appropriate amount of power necessary to achieve the temperature set point, in the allotted amount of time. "This approach is much safer, and more efficient than simple power and time control," Anderson adds. A temperature sensor provides feedback for power levels from the sample temperature, without applying too much power and risking damaging the microwave vessels, or applying too little power and not fully digesting the sample. Computer control monitors each reaction (in multi-sample digesters) and records relevant parameters at every stage of the digestion, thereby providing consistent output for every sample in every run.

CEM's MARS 6 microwave digestion system incorporates hundreds of pre-programmed methods and built-in sensors that detect which vessel set is being used, and each vessel's required power.

Achieving consistency

Achieving digestion consistency requires that samples be homogeneous and representative of the original sample. Anderson recommends reducing the sample's particle size, before digestion, through milling or grinding to improve contact between acid and sample. "In some instances, samples require heating to promote mixing," she adds.

Digestion vessel geometry and materials of construction affect the efficiency of microwave digestions. Sample cup geometry may affect both digestion efficiency and sample recovery. Reduced-volume vessels, for example, may be a good choice for expensive or scarce materials, or for workflows where users seek to minimize risks associated with hot, pressurized hazardous materials.

Vessels from Parr Instrument Company (Moline, IL) use a heat-stable microwave-transparent polymer for outer containment, which also serves as a thermal insulator for the PTFE (Teflon®) sample cup. "With heating developed internally within the cup, temperatures in the outer vessel seldom exceed 50 C," says Dr. Henry Albert, technical director at the company. The PTFE sample cup is closed with a self-sealing PTFE O-ring, which eliminates the need to preload the cup or use any tools to secure a tight seal. This also eliminates the effects of differential thermal expansion during heating and cooling cycles, while providing a chemically inert, all-PTFE wetted system. "PTFE digestion vessels exhibit unique inertness to strong acids at high temperatures," Albert says. "The material allows energy to flow directly to the sample while also serving as an insulator to restrict heat flow from the reaction zone."

On the negative side, PTFE has a tendency to creep or flow under pressure or load, a tendency evident even at room temperature but accentuated at higher temperatures, especially above 150 °C. PTFE creep makes achieving tight seals difficult and may lead to deformation and shorter usable life for PTFE components. PTFE is also somewhat porous, which may result in vapor migration across the cover seal and through the wall of the liner itself. Parr minimizes these issues by fabricating components from virgin PTFE molded to an optimal pressure to minimize porosity. While the amount of solute lost during normal digestion is negligible, vapor migration into the walls of the PTFE cup will occur and is unavoidable.

Lab managers who are unfamiliar with microwave digestion enjoy a range of resources for achieving consistency. "The best place to look first is the application team of your microwave system vendor," says Anderson. Most vendors offer training courses and will advise users on specific samples and likely safety issues.

Purchasing decisions

Labs should consider the suitability of the microwave system to sample type, daily throughput and workflow, and application support. Manufacturers offer many different vessel types and geometries, and these must be matched to sample and throughput as well. Higher-throughput vessels, appropriate for many EPA methods, allow digestion of large batches at moderate temperatures and pressures. "However, difficult organic samples such as heavy oils and plastics, and many inorganic samples, require temperatures and or pressures that are not suitable for this vessel type," says Anderson, "and therefore require a higher-performance vessel to digest samples completely. For this reason, reviewing the samples you intend to run in the microwave prior to purchase can save you a lot of money."

Daily throughput will dictate whether a sequential microwave or batch microwave offers the best workflow option for a particular lab. "If you digest a lot of the same samples every day, you will achieve better throughput in a batch microwave that can digest 24 to 40 samples at a time," Anderson says. "On the other hand, if your laboratory prepares a few samples of various sample types, then a sequential system may be the best choice as it allows you to run any combination of samples and acids in the 24-position autosampler."

In sequential systems, samples enter the microwave cavity with the help of a robotic arm and every sample is precisely controlled. This gives laboratories tremendous flexibility to prepare a wider range of samples. Each sample is then digested, cooled, and placed back into the rack in about 10 minutes, or a full batch of 24 samples is digested in about four hours. Operation is fully walk-away.

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FOR ADDITIONAL RESOURCES ON MICROWAVE DIGESTION, INCLUDING USEFUL ARTICLES AND A LIST OF MANUFACTURERS, VISIT WWW.LABMANAGER.COM/MICROWAVE-DIGESTION

technology NEWS

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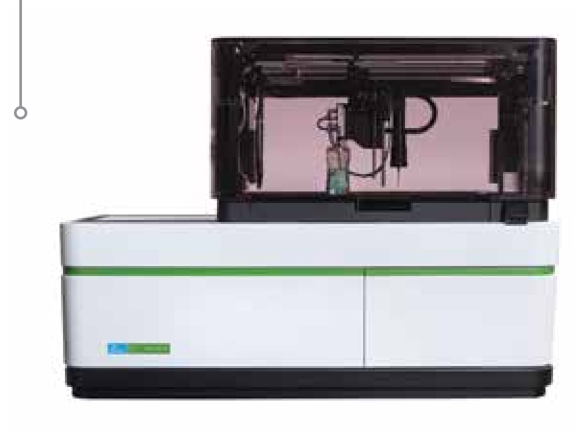

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LM ONLINE

We look back at our web content since the January/February 2020 issue and look forward to what's in store for the April issue.

1 Creating Cohesive LED Lighting within the Laboratory Environment

With its combination of energy savings, durability, and low-profile construction, the light-emitting diode (or LED) has quickly become the lighting technology of choice. But it is still important to understand some criteria that should be considered when incorporating lighting into the laboratory environment.

Read more at **LabManager.com/LED-lighting**

2 Trending on Social Media

As of February 11, *Lab Manager*'s top Jan/Feb issue article posted to social media was our Business Management article, "Dos and Don'ts of Running a Lab." This piece discussed how to avoid common pitfalls of managing a lab, and offered tips on topics like scheduling, teamwork, and running meetings.

Read more at **LabManager.com/management-101**

3 Most Popular Webinar

Our most recent top webinar on LabManager.com with 325 registrants was "What Health and Safety Leadership Really Means." To drive superior lab safety performance, leaders need to align their words, actions, and personal behaviors with their lab safety priority. This Safety First webinar was led by Scott Hanton, who will be a featured speaker at the 2020 Lab Manager Leadership Summit, June 1-3 in Nashville. Though it ran on February 11, you can still register to watch on-demand.

Read more at **LabManager.com/safety-leadership**

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NEXT ISSUE ➡ Sustainability

Operating a lab facility and conducting research in a sustainable way has become a top priority for most labs in recent years, but following through on sustainability goals can be challenging. This article will discuss both small- and large-scale "green" solutions that can be implemented to make a systematic change in the lab, and explain why following sustainable practices in the lab is not only beneficial to the environment, but makes good business sense as well.

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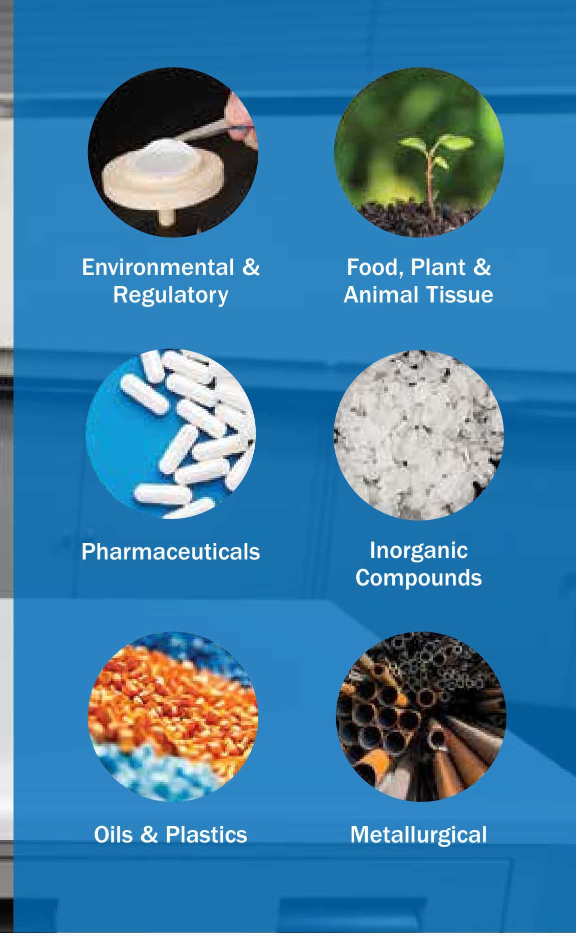

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