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contents

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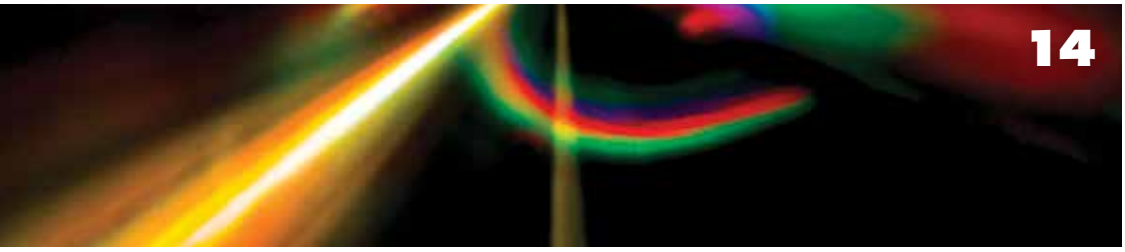

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BPA WORLDWIDE BUSINESS

DEPARTMENTS

driving innovation through diversity

Imagine working in an environment where all your colleagues are your age. They grew up in the same region as you. They have similar life experiences to yours, as well as the same educational background. What would your daily workday feel like? What conversations would you have with your colleagues? Would you learn anything new? Would you feel motivated to go to work each day?

This scenario just briefly scratches the surface of why diversity is essential in the workplace, particularly in scientific fields where new ideas and innovation are necessary to succeed.

The topics covered within these pages are crucial for today's lab leaders to understand and actively participate in. The featured articles included in this issue are meant to serve as a starting point for further discussions, and act as motivation for lab professionals to ask questions about diversity, equity, and inclusion (DEI) within their workplace. These articles also offer suggestions for ways to implement new strategies in your lab, to help address any potential areas of improvement.

The issue kicks off with our cover piece, "The Power of Diversity", on page 10. Sherri L. Bassner, PhD, pulls from her decades of experience as a scientist and manager to offer our readers insight into how lab leaders can create a culture that welcomes diverse input and creative thinking. When evaluating DEI in the workplace, Bassner tasks lab leaders with taking a look at themselves first. As she notes, leaders set the tone for behavior in the work environment. So, what does your behavior say? How does your behavior contribute to the overall culture?

Our Leadership & Staffing article builds on the topic of creating an inclusive work environment by discussing how trust plays a large role in making this happen. "Employees need to trust their organizations and managers will do what's right, act in their best interests, and dedicate the required resources," writes contributing writer Donna Kridelbaugh. If employees don't trust their superiors, they are much less likely to participate in group settings, offer meaningful feedback, or give their best effort to the organization's mission. "By showing your vulnerabilities [as a leader], employees will be more trusting that their differences will be accepted and appreciated," adds Kridelbaugh. Turn to page 24 to learn more about how to foster open communication, advocate for all employees, and show vulnerability as a leader.

The articles discussed above address the leadership aspects of DEI, but how can the actual design of a lab play a role? Our Lab Design article (page 28) emphasizes how thoughtful lab design can accommodate everyone's needs. "It is critical to consider the holistic view of the experience of members of the research team, and not just their time spent performing benchwork," says Christiana Moss.

You can hear from additional experts on similar topics by viewing Lab Manager's Diversity Digital Summit, which took place earlier this year. Register to watch on demand at summit.labmanager.com/diversity.

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MANAGER MINUTE

Three Keys to Improve Equity in the Lab

by Scott D. Hanton, PhD

Diversity, equity, and inclusion (DEI) are very important activities in all businesses to take advantage of the various strengths and experiences that each staff member brings to the lab. While diversity efforts have been going on in many organizations for years, equity and inclusion are newer efforts and can be challenging for many lab managers. While both are focused on fair treatment of people, equity is different than equality. Equality treats everyone the same regardless of need, while equity treats people differently dependent on need. Here are three tips that will help you improve the equity in your lab, hopefully resulting in more fairness and opportunity for all staff.

#1 – Be transparent

Be transparent about opportunities, decisions, resources, and challenges. Don't assume that everyone on staff sees the decisions and opportunities in the same way. Communicate clearly and openly about what is happening in the lab, and what might happen in the lab in the future, with everyone. By becoming more aware of how the lab functions, every staff member can generate a clearer understanding about how their skills and experience can contribute. By communicating openly about opportunities, everyone has an equal chance to realize their potential.

#2 – Listen for needs

Since the key to equity is treating people differently based on their need, it is vital for lab managers to listen carefully for the needs of staff. It is important to realize that staff members might have very different starting points in their scientific careers, and may need different things, training, or coaching to have an equal chance to successfully act on the next opportunity. These different needs may require lab managers to listen differently, and to become more aware of the specific needs of individuals, rather than responding to typical or average needs of the group.

#3 – Improve fairness

It may be time to investigate some basic fairness aspects of the lab—things like equal pay for similar work, effective access to opportunity, appropriate access to training, and generating the right developmental experiences for staff. While many labs claim to have fairness in place, there are still many stories shared by lab personnel about unequal pay, access to opportunity, and access to resources. Many labs get trapped into the habits of their past and stop seeing these issues as fairness, and just accept them as local fact.

Lab managers can play a very important role in improving equity in the lab. It takes looking at the people and processes of the lab with new eyes, looking for the important differences and ensuring that everyone on staff has equal opportunity to rise to their potential.

Thanks for reading. I hope you can use this information. I am very interested in hearing from you. If you have feedback or comments on this set of tips, or suggestions for future Manager Minutes, I'd love to hear from you. Please reach out to me at ***shanton@labmanager.com****. I'm looking forward to our conversations. Thanks.*

THE POWER OF DIVERSITY

Different experiences and perspectives bring new ideas and solutions to the lab

by Sherri L. Bassner, PhD

For more than three decades, lab managers have been wrestling with the challenges of developing diverse workforces and building an inclusive culture to take best advantage of the strength of those differences. The issues and challenges are broad and deep. This article is intended to uncover some of the nuances of this topic and inspire lab managers to further pursue strategies and actions.

Any discussion of diversity and inclusion must begin with definitions, or at least an understanding of what the terms are intended to represent. True "diversity and inclusion" means recognizing each individual as the unique combination of experiences and perspectives that they represent, and creating a culture that allows each individual to contribute to their fullest ability.

These, of course, are lofty and difficult goals. However, as with targets of "zero lab safety incidents," the difficulty of achieving the end point should not inhibit aggressive actions to attain it. Each action along the way toward true diversity and inclusion provides incremental benefit to the business and all within it.

Diverse representation in the workforce

As a first step toward the creation of a more diverse workforce, many organizations use proxies as representations of difference. The most common proxies are gender, race, national origin, and sexual orientation/gender identity. Some less common proxies include education level or university, a region of the country someone grew up in, and even social or economic class or background. Even with several decades of focus, efforts along these lines have had mixed success. For example, data from the Census Bureau[1] show that women have made significant gains in STEM employment in the physical sciences, growing from 15 percent of the workforce in 1970 to 41 percent in 2011 (approaching the 50 percent representation in the workforce as a whole). Blacks and Hispanics have not fared as well. Those groups are represented in STEM fields at less than half of their representation in the workforce as a whole. Data exist on many other measurable aspects of difference, but that is only the beginning of the story.

> "To truly unlock the power of their workforce, the lab manager needs to create a culture that invites broad input and creative thinking."

The intent on increasing representation of these proxy groups in the workforce is that people from different backgrounds will bring different experiences and perspectives into the workplace. As scientists, we are well aware that the best ideas often come from the intersection of existing knowledge bases. In fact, entire new fields of study arise when scientists with different backgrounds come together to solve problems. Biochemistry became its own field of study when biologists and chemists began to work together to understand the chemical processes behind living systems. Neuroeconomics is an emerging interdisciplinary field aimed at understanding human decision making. The power of a diverse workforce is that those different experiences and perspectives bring new ideas and ways of solving problems into daily discussions.

Measuring success

So, does it really work? The difficulty, of course, is that we cannot run a true control experiment. We cannot take an organization of similar people from similar backgrounds and simultaneously have an organization with a diverse workforce facing the exact same conditions and challenges and see which business performs better. There are always confounding conditions, as well as the challenge of cause and effect: does an organization perform better because of its diverse workforce and inclusive culture, or do well-performing businesses have the resources and bandwidth to support such an environment?

There are, however, recent studies that point to the performance and financial benefits of investments in diversity and inclusion. Boston Consulting Group, in an article published in 2018[2], focused on "innovation revenue" as a function of "diversity score" and found that companies with a higher diversity score (defined as diverse representation on their leadership teams) outperformed those with a lower score (as measured by percent of revenue from products and services launched in the preceding three years), 47 percent to 26 percent. McKinsey in 2020[3] focused on financial outperformance compared to national industry averages. They found that gender diverse companies outperformed their industry average by 25 percent while those companies considered ethnically diverse outperformed by 36 percent.

While these studies have necessarily focused on those proxy measures for a diverse workforce, the rational lab manager understands that their goal is to leverage the uniqueness of each employee. Representation across a number of historically underrepresented groups is not enough. Beware of the trap of different outward appearances cloaking similar thought processes. To truly unlock the power of their workforce, the lab manager needs to create a culture that invites broad input and creative thinking. This culture creation is difficult, requires consistency and persistence, and above all, begins

with the leader doing a self-evaluation. Consider the tips below as a starting point on the journey of creating a truly inclusive workplace culture.

Strategies for lab leaders

Since the leader sets the tone for behavior in the work environment, the place to begin is with that leader taking a hard look in the mirror. The challenge of uncovering unintentional bias is too complex for this short treatment and the reader is encouraged to seek out further guidance. An important note—the goal, to quote Brené Brown, is "to get it right, not be right."

Everyone carries unintentional bias. It will never be eliminated. The objective is to constantly work to be aware of bias and challenge biased thinking. This is a never-ending journey for all of us, and the expectation needs to be on learning and improving, not eliminating and perfecting.

In addition to understanding their own unintentional bias, the leader needs to get comfortable with discomfort. If the goal is to bring new and creative thinking to the table, then ideas that don't fit the leader's experience and thought processes are going to need to be nurtured, not dismissed. This is counter to how many leaders have been coached and developed, as well as counter to the confidence the leader has developed in their own preferred ways of approaching a problem or achieving a goal. An old joke among managers about empowerment says that, "Anyone is empowered to make the same decision that I would have made." Making room for other approaches requires intent on the part of the lab manager. That intent includes asking for other thoughts, not dismissing an idea without serious investigation and discussion, and modeling this behavior consistently for the rest of the workforce. Changing natural behaviors requires conscious thought, the aforementioned intentionality, and consistency. It must be front of mind and thus a top daily priority.

Once an employee sees that their ideas are getting a solid hearing from management, they will be encouraged to bring these differing thoughts forward more broadly. This is exactly what the leader wants, but if the broader culture is not skilled in constructive debate, then the openness will quickly shut down. This ability to listen to and build on ideas different from your own is a learned skill. The skill building in constructive debate also needs to be tied to the right incentive structure to encourage both the comfort in bringing forward new ideas, as well as the desire to build on them usefully. Since this sort of cooperative idea building is counter to the instincts of many in a competitive lab culture, the leader needs to actively teach that capability, and consistently reinforce its use.

"In addition to understanding their own unintentional bias, the leader needs to get comfortable with discomfort."

The business case for diversity has been discussed, debated, and measured for decades now. Most agree that greater inclusion of different thinking is critical to the competitive differentiation of any business. While many companies have focused on the easiest component—increasing representation of historically underrepresented groups—the true impact of a diverse workforce is only possible with the creation of an inclusive culture. Building this culture is a difficult but powerful undertaking. Investing in yourself as a leader and in your organization is worth the effort. The difference between a good business and a great business is the discretionary effort employees choose to contribute. Having a workforce truly diverse in their thinking unleashed in an environment that values that broad range of ideas should be every lab manager's top business goal.

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***Sherri L. Bassner**, PhD, is a retired chemist and manager who spent 30 years developing new products and services, and then leading others in those same efforts. She is a part-time leadership coach and blogs on personal and professional development (among other topics) at www.sherribassner.com.*

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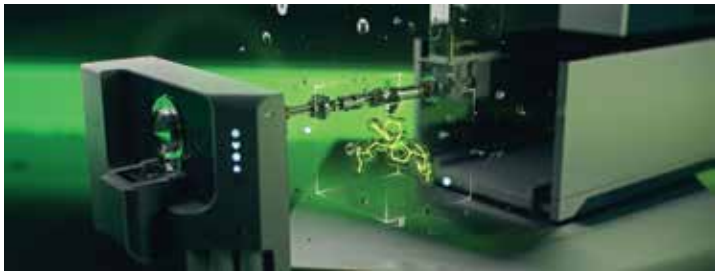

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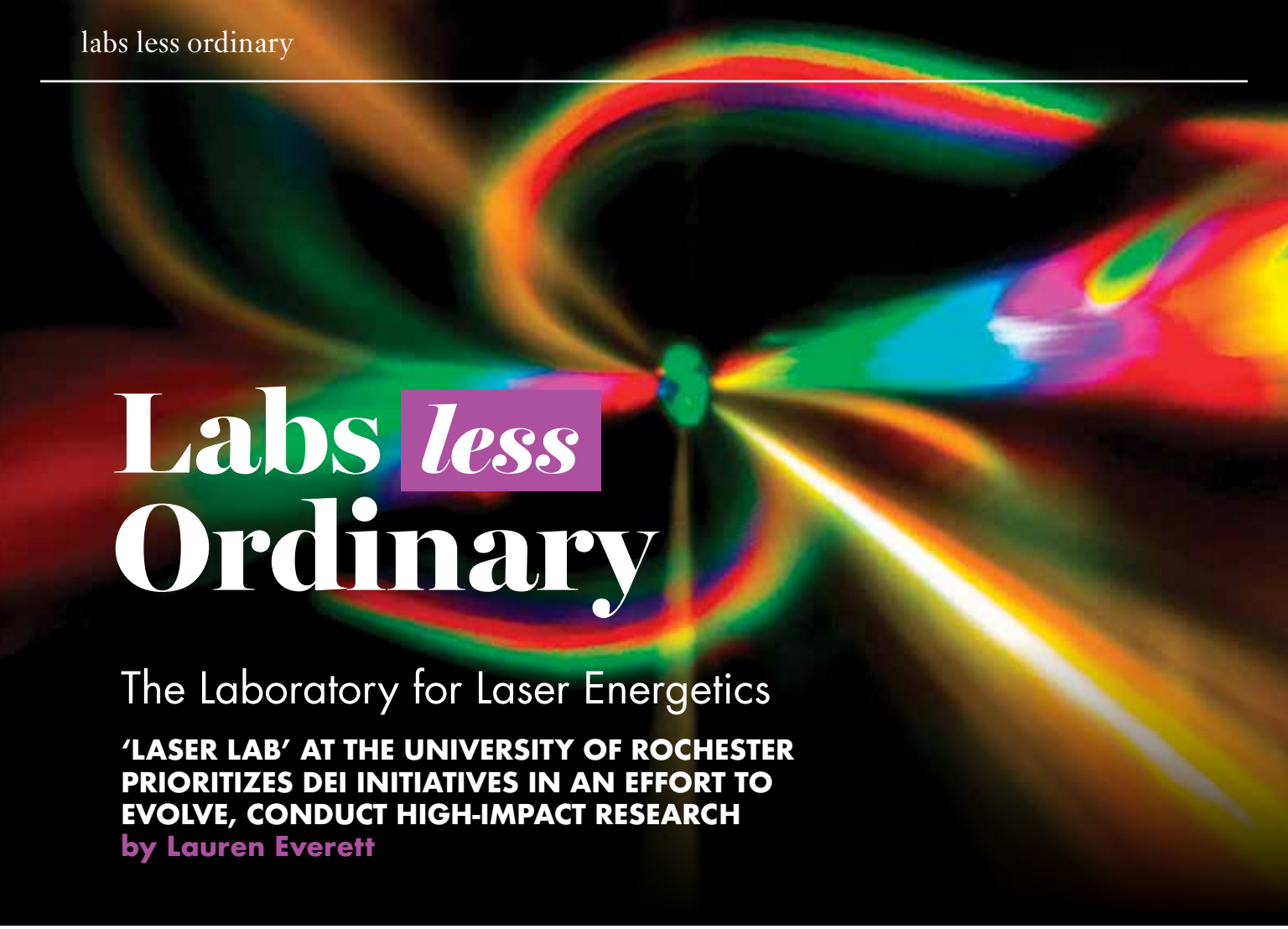

Labs *less* Ordinary

The Laboratory for Laser Energetics

'LASER LAB' AT THE UNIVERSITY OF ROCHESTER PRIORITIZES DEI INITIATIVES IN AN EFFORT TO EVOLVE, CONDUCT HIGH-IMPACT RESEARCH

by Lauren Everett

▲An image of light passing through a combination of refractive and diffractive axicons, referred to as a Graxicon, shows the unusual color dispersion created by this optical system.

The University of Rochester's Laboratory for Laser Energetics (LLE) houses a variety of unique and sought-after instruments, including the most powerful laser of any academic institution in the world. As one recent example, its OMEGA laser system was used by an international research team—including scientists from Lawrence Livermore National Lab, the French Alternative Energies and Atomic Energy Commission, and the University of California, Berkeley—to help confirm that helium rain is real, and could potentially occur on Jupiter and Saturn. The research was published by *Nature* in May.

OMEGA measures 10 meters tall and is approximately 70 meters in length. As explained on the LLE site, "the system delivers pulses of laser energy to targets in order to measure the resulting nuclear and hydrodynamic events. OMEGA's 60 laser beams focus up to 30,000 joules of energy onto a target that measures less than one millimeter in diameter in approximately one billionth of a second."

> "A diverse workforce is vital to thriving science programs in the United States."

LLE is also recognized as a major training facility for those involved in high-energy-density science. The facility focuses on five primary areas of research—high-energy-density physics; plasma physics; high intensity laser-matter interaction; high-power laser research including coherence control for focal spot smoothing and controlling the laser light interaction with matter; and optical material science and technology. LLE scientists hold more than 65 patents in a wide variety of fields, and more than 14 licenses for the use of these patents in commercial products have been issued. The 2018 Nobel Prize

1. The first building of University of Rochester's Laboratory for Laser Energetics (LLE) complex was built in 1976 to house the OMEGA laser facility and supporting research laboratories. **2.** Experimental technicians inside the OMEGA facility target chamber. **3.** A close-up view of the inside of the OMEGA target chamber shows a spherical shell being symmetrically imploded by 60 focused laser beams along with various physics diagnostics. **4.** LLE engineers and scientists align the optics associated with an ultrafast optical parametric amplifier to achieve high laser beam quality. *Credit for all photos: LLE*

in Physics was won by a graduate student, Donna Strickland, and her thesis advisor Gerard Moreau for inventing new ways to make ultra-high-power lasers. At the time of the award, Donna was only the third woman to win the Nobel in Physics, and the first in 58 years.

LLE has expanded and evolved since it first opened in 1970 as the Laser Fusion Feasibility Project. The OMEGA 24-beam laser facility was added in 1985, becoming the first ultraviolet fusion research facility. Since then, the OMEGA facility has upgraded to 60 laser beams (12 of which were used in the *Nature* research), and the OMEGA Extended Performance Petawatt-scale laser was completed in 2008. Due to this continued growth of the OMEGA facility, the LLE staff increased from fewer than 100 people to more than 350. There are also approximately 200 students from high school to graduate school involved in research.

And the evolution of LLE is continuing. The LLE staff is in the works of submitting a proposal to the National Science Foundation to construct a state-of-the-art, short-pulse, multi-Petawatt laser facility, referred to as EP-OPAL. As Terrance Kessler, senior research engineer and diversity manager of LLE, explains, "This mid-scale infrastructure would enable important, high-impact science that has been

defined by a broad community interested in high-energy particle beams, relativistic plasma physics, ultrahigh-field science, materials science under extreme conditions, and extreme sources of x-ray, gamma-ray, and high-energy particle radiation for nuclear physics and applications. This project would establish a facility for short-pulse laser-enabled science addressing a major national need in the mission space of the National Science Foundation."

Shining a light on issues of diversity, equity, and inclusion in science

Physical expansion isn't the only way LLE has evolved The team at LLE is actively engaged in diversity, equity, and inclusion (DEI) programs, to ensure their facility represents a wide variety of experience, backgrounds, perspectives, and knowledge. In 2019, LLE developed its diversity council, which consists of eight scientists, engineers, and technicians. Shortly after, LLE applied to join the American Physical Society's (APS) Inclusion, Diversity, and Equity Alliance (IDEA), and announced its acceptance into the alliance in June 2020. This program has a mission of "empowering and supporting physics departments, laboratories, and other organizations to identify and enact strategies for improving equity, diversity, and inclusion," the site states. The LLE director, E. Michael Campbell, fully supports this move toward cultural change and has expressed his commitment to DEI, stating, "A diverse workforce is vital to a thriving science program."

"Participation in the APS-IDEA program has provided opportunity to understand and embrace cultural change in our workplace," says Kessler. The various discussion topics explored in our meetings, including change theory, shared leadership, institutional norms, storytelling, and recruitment pathways have helped us carry out an informed plan to create a diverse and inclusive work environment."

Kessler, who has worked at LLE for 45 years in various roles, has now added "diversity manager" to his titles. "After completing four decades of scientific and technological research and management, I realized that I could no longer ignore the lack of diversity, equity, and inclusion in physics both in the US and around the world," he says. "People with much more experience than myself encouraged and persuaded me to use whatever amount of privilege and power I have toward creating cultural change in the communities I live and work."

Kessler, as diversity manager, and the diversity council lead numerous DEI initiatives for the lab, and strive to find areas of improvement toward a more inclusive culture for both lab staff and university students.

Recognizing that less than 20 percent of LLE's approximately 400 scientists, engineers, technicians, and graduate students were women, LLE developed the WISER (Women in Science and Engineering at Rochester) program. The program, coordinated by distinguished scientist Radha Bahukutumbi, also a member of the LLE diversity council, holds workshops and offers mentorship for women graduate students and early- to mid-career researchers.

One of Kessler's first projects as diversity manager was the development of the BEST (Broad Exposure to Science and Technology) Student Research Experience. The goal of the program is to expose local high school and first-year college students from underrepresented groups to areas of science and technology involved in laser energetics research. Through this experience, students can learn the different career opportunities available to them in a similar field.

As a next step, the diversity council is hoping to develop a conference, through its collaboration with APS, for undergraduate women in physics. The lab already hosts numerous seminars on unconscious bias, IDEA programs, women in STEM, and other topics, at the university. Kessler notes that these topics are often well received, but acknowledges the sensitivity and sometimes controversial nature of addressing DEI in academic and work settings. Although conversations around DEI can feel challenging at times, it is crucial for leaders in STEM fields to participate.

"Laboratory leaders need to hold themselves accountable by first owning their current situation regarding the level of workforce diversity, how inclusive their work environment is, and to what extent they believe in maintaining equity at all levels," says Kessler. "An institutional dashboard should be created and shared with all stakeholders and with the external community. They need to own the truth and be willing to share the rate at which workforce diversity changes; either increasing or decreasing."

As Kessler explains, LLE has introduced leadership accountability by including elements of DEI into employee self-assessment and performance evaluation processes. "DEI is now embedded in this process, and each employee is given the opportunity to consider their role in creating cultural change in the workplace."

***Lauren Everett**, managing editor for* Lab Manager, *can be reached at leverett@labmanager.com.*

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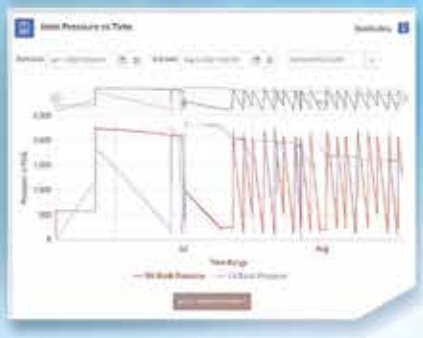

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Addressing the Science Gender Gap

WHAT A METRICS-DRIVEN APPROACH CAN DO FOR FEMALE CAREER PROGRESSION

by Louise Madden

The diversity of roles available in the science arena is broader now than ever before, with more women taking on management roles in STEM, including an increasing number in senior and board positions. That said, in a pre-pandemic report on women in science, UNESCO reinforces that this is still far from being the norm, with women employed in scientific R&D across the world accounting for less than one-third of the workforce, with a global average of 29.3 percent. Although progress is being made, it is clear there is still much work to be done to reduce this gender gap.

> "Annual performance reviews are a great source of crucial metrics to broaden understanding and map organizational progression."

Addressing this gap will require a metrics-based approach from driven and ambitious company leadership. The approach should focus on improved recruitment and development strategies that apply metrics and guidance to help remove barriers and empower women into science careers.

Find the broadest mix of candidates

To attract the best candidates, recruitment strategies must evolve in line with current networking practices. To bring in more female applicants for a diverse, enriched workforce, a different and more proactive approach to advertising must be taken to ensure job opportunities are displayed in places where women will see and engage with them. Social media is an effective platform for this, with its potential for demographic targeting allowing gender, location, age, and interests all to be factored.

The power of social media engagement is not always recognized. Senior and management teams, and especially women in these roles, should never miss the chance to like, share, and comment on recruitment posts. By amplifying across their own networks, they can broaden the reach of the ad within a very targeted demographic while adding their own endorsement. The use of social media also encourages a shift away from headhunter-led recruitment who may have their own in-built bias to what science candidates "should" look like.

The real advantage of social media and online platforms are their powerful built-in analytics, which, when exploited, can be used to establish metrics around reach, audience engagements, and conversion. These metrics can be leveraged for further recruitment campaigns to better target women.

In addition to social media platforms, the use of blogs not only provides the advantage of measuring and applying metrics, but also sets out and reinforces a company's ambitions and culture in a long form. As an example, the H.E.L blog published a piece to mark the 2021 International Day of Women and Girls in Science that showcased the career experiences of women in a range of functions and at various levels in the company.

Importantly, the objective of the post was to aid women in science, and those considering science-based roles, to better navigate their career trajectory. However, it was also intended to have a broader reach to engage men, and to particularly resonate with male leaders, enabling them to understand how they can help develop the careers of their female team members, especially given that ~68 percent of H.E.L's overall web traffic comes from men.

The question of quotas

Always take the time to record and review gender data across every role recruited to understand your candidate mix and whether this maps against corporate targets. This data can be used to inform future recruitment campaigns and ensure progress is being made. However, setting and enforcing recruitment quotas alone will be of limited value.

Instead, CEOs and senior management need to set and widely share diversity goals and lead by example. Senior staff should adopt an ethos of encouraging and accepting candidates for roles across all departments regardless of gender, and without preconceptions of what are the more "female-suited" roles.

The key metric to look at during recruitment is the gender mix of candidates at the initial application stage. If the gender mix isn't close to 50/50 in your applicant pool, it's challenging to have equal representation of male and female candidates at the later stages of recruitment. Once you achieve the correct candidate pool mix, it creates the right environment for true balance within an organization.

If the gender mix is consistently imbalanced, then you may have to look at the potential factors causing this—are you advertising your jobs in the wrong place? Do you have a culture or reputation that might put women off from applying to work for you? Are you demonstrating career progression for women within your organization? Chances are that your candidates are considering other employers and if you're not standing out, it's time to ask why and fix it.

Starting with the right candidate pool mix is preferable to setting percentage targets for recruitment. Strict hiring percentages can backfire, creating an "enforced reality" where the best candidates cannot be recruited because quotas do not allow for it. Having strict quotas in place also removes the opportunity to stand back and consider the balance an organization or team needs as a whole, obscuring the qualities that would be most beneficial. For effective recruitment, people should always take precedent over metrics.

Opportunities come from greater flexibility

The lockdowns and disruptions of the last 18 months may have taken awhile to get used to, but they have created a sea change of opportunity in the area of flexible working. It is hoped this will become a new normal and strengthen the attraction of women to the sciences.

Now that flexible- and home-working has been experienced by so many, it is time to question whether a Monday-Friday, 9 a.m. to 5 p.m. ethos most benefits an organization. Instead, metrics can be built around task-focused activity across all departments. For example, finance can be left to produce management accounts by day five regardless of when/where they work, and R&D will be able to deliver complex tasks to deadlines if equipped with appropriate software that allows effective cross-team home-working. These activities should always be backed by installing systems that track progress and delivery, so management is reassured that deadlines are being met. With these attitudes in place, removing core working hours from contracts shouldn't be too far away. This would be a major step forward in terms of giving women the power to achieve a work-life balance without compromising their career choices or progression.

Take a long-term view on female development

Not every woman will take a career break to have children, but more often than not for those that do, the lion's share of childcare responsibility falls to them for a host of very practical reasons. This inevitability means it shouldn't come as a surprise when it happens, but nor should it curtail a woman's career. The remedy is to prepare for such events and to understand at the organizational level that bringing women into leadership roles may take a little longer, or require a different approach to that of a male peer. While the goal is very much the same, how it is achieved may not be—one size will certainly not fit all.

Regardless of these challenges, the aim should always be to run a strictly meritocratic organization that values diversity and avoids conscious or unconscious bias within its recruitment and development processes.

Annual performance reviews are a great source of crucial metrics to broaden understanding and map organizational progression. Their focus shouldn't be restrained to the now, but take a forecast view of upcoming roles and structures, and the impact women in the business could be having as far away as 10 years from now.

Feed performance data from staff reviews into a human capital plan to create a roadmap of internal progression for all talented individuals. Make sure these "future stars" know they have been talent-spotted and talk to them about their aspirations. Find out and record their career interests and where they see themselves in five and 10 years. Also, make their line managers aware of your thought processes so they can be involved in developing roles that see career aspirations nurtured regardless of gender. The alternative—waiting for another staff member to leave and then seeking an internal replacement—is just too late. Remember, human capital plans should be a key tool used throughout career development for business continuity and not just taken up at times of expansion.

When looking at human capital plans, ensure you evaluate the gender mix at all levels in the organization. If possible, plan to improve the gender mix of the leadership team as the company evolves, by promoting the company's most talented female staff internally. However, measuring company metrics for promotion should go hand-in-hand with the personal experience of leadership staff when deciding team structure—you know your people, you're in a management role because of your ability to see the future. Nothing is stopping you from building the right gender balance in your team now and using your network within the company to get the best talent to come work for you. Like hiring new employees, it's a war for talent, and if you get a reputation for hiring well and fairly, people will want to work with you.

Champion variety

Twenty-first century science holds a broad range of roles, and there is room for everyone who wants to be here. Ways of working, policies, and procedures need to realize this and ensure that they apply to all. Having the right team in place is what matters, and metrics have a role to play in helping to discover and manage them. Ultimately, it's worth remembering that people are the lifeblood of any organization, but metrics provide a useful methodology to find and keep the very best. Support both the organization and the employee to achieve their long-term aspirations.

Louise Madden *has been CEO at H.E.L Group for two years and her career in the science industry began in 2005. Follow her on LinkedIn: www.linkedin.com/in/louisemaddenhel.*

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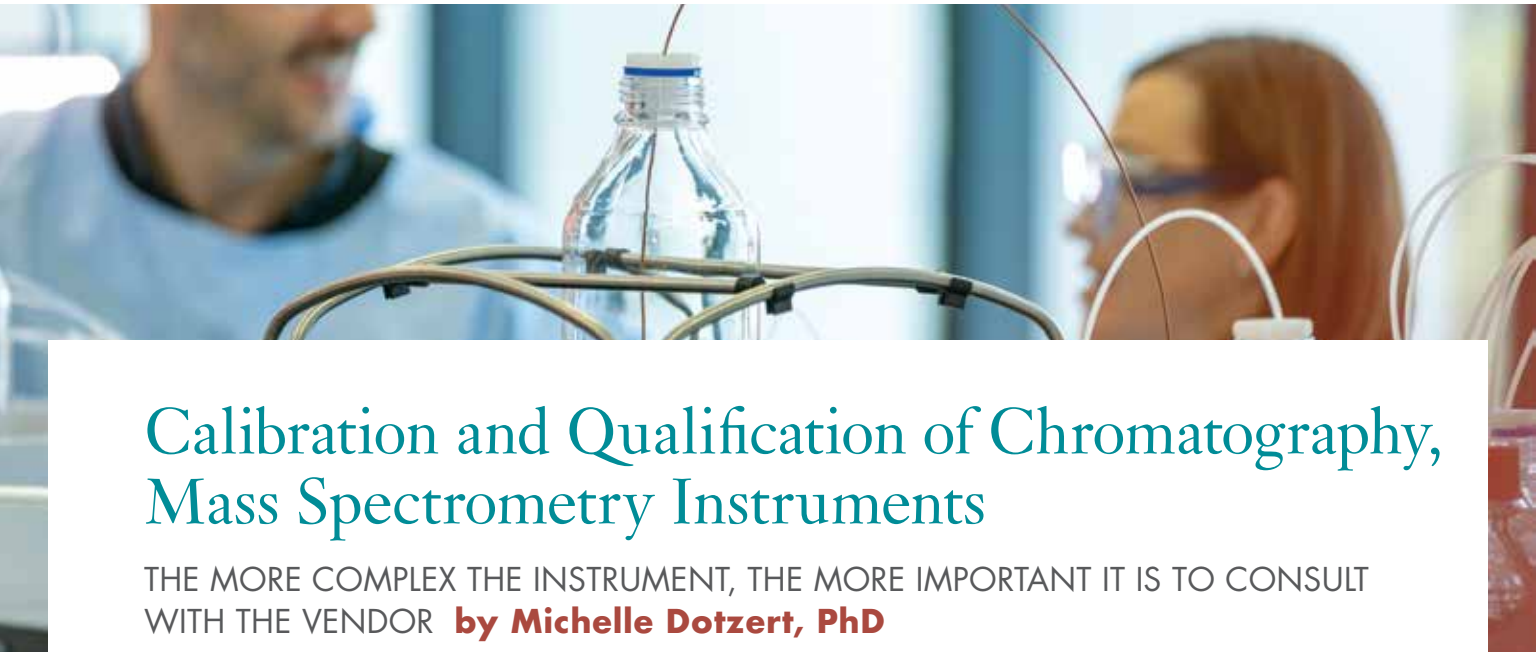

Calibration and Qualification of Chromatography, Mass Spectrometry Instruments

THE MORE COMPLEX THE INSTRUMENT, THE MORE IMPORTANT IT IS TO CONSULT WITH THE VENDOR **by Michelle Dotzert, PhD**

Liquid chromatography (LC) and mass spectrometry (MS) instruments require calibration for optimal performance and accurate identification of analytes of interest. In regulated laboratories, these instruments must be calibrated before they go online, after maintenance activities, and after major repairs—a process called qualification.

Qualification is the documented verification of accuracy, linearity, and other system attributes as intended by the vendor. Qualification requires significant expertise, and with increasing instrument complexity, consulting with the vendor will yield the best results.

> "Any contamination of the solvent, sample, or system can be detrimental to proper calibration and accuracy of results."

When to calibrate

Ken Moore, PhD, MS curriculum manager at Waters Corporation, provides some insight into how frequently MS systems should be calibrated. He recommends checking or calibrating time-of-flight mass spectrometers daily, whereas quadrupole mass spectrometers will generally be calibrated a few times each year. With consistent laboratory conditions—temperature and humidity—the instrument may require less frequent calibration, "but should be checked regularly," says Moore. He also cautions that if masses drift from expected values, the instrument should be calibrated.

Should laboratory staff perform qualification and calibrations?

According to Moore, there are several factors that determine the risks associated with performing qualfications. These include the level of expertise required, laboratory standard operating procedures, how well the laboratory staff has been trained, the need for cleaning, maintenance, or repair procedures prior to calibration, and instrument complexity. "The greater the complexity of the MS instrument (for instance, time-of-flight or advanced MS detection systems), the more important it is to consult with the vendor when it comes to qualification," he explains.

There are also factors that can reduce the risk associated with users performing mass tuning and calibrations. Moore recommends periodic cleaning and maintenance, as well as choosing MS systems with automated calibration to reduce variability between users. He also notes that vendor-certified training programs can minimize the risk of improper calibration.

The process and challenges

The calibration process involves infusing several compounds of known mass to construct a calibration curve, which allows the user to maximize the mass accuracy of the instrument. To ensure the instrument achieves the best resolution and highest sensitivity, a tuning procedure is performed. "A typical tuning

procedure infuses a known compound and then alters the voltages of the instrument to maximize signal," explains Moore.

"Laboratories should ensure good laboratory practices and standard operating procedures are in place prior to routine tuning and calibration."

Calibration and tuning require proper sample preparation and sample dilution. It is also important to work with calibrated pipettes, and ensure standards are stored properly. Any contamination of the solvent, sample, or system can be detrimental to proper calibration and accuracy of results, says Moore.

To support traceability, Moore recommends documenting evidence of who performed the calibration and when, as well as the compounds used, and methods using compliant-ready software systems. He also notes that calibration standards should be pure and contaminant-free. Laboratories should ensure good laboratory practices and standard operating procedures are in place prior to routine tuning and calibration.

Properly calibrated and tuned instruments are important for accurate, reliable data. Given the complexity of chromatography and mass spectrometry instruments, laboratories should invest in proper training or consult with vendors before undertaking these tasks.

***Michelle Dotzert**, scientific technical editor for* Lab Manager, *can be reached at mdotzert@labmanager.com or 226-376-2538.*

Modeling Inclusive Behaviors to Build Trust with Staff

LAB MANAGERS SHOULD MODEL INCLUSIVE BEHAVIORS TO CREATE A TRUSTING ENVIRONMENT WHERE ALL EMPLOYEES CAN SUCCEED **by Donna Kridelbaugh**

Today's increasingly diverse and global workforce values an inclusive environment. Companies that demonstrate their ability to evolve and provide an inclusive, trustworthy work environment will see the positive effects through recruitment and retainment of top talent, and higher levels of employee satisfaction and engagement. This will boost creativity and innovation, and keep up with changing markets and technologies.

For this work to succeed, it first requires an organizational commitment to promote an inclusive culture, which is predicated by a climate of trust. Employees need to trust their organizations and managers will do what's right, act in their best interests, and dedicate the required resources. As agents of organizational change, managers should lead by example and model inclusive behaviors to create a trusting environment where all employees can succeed.

> "Employees need to trust their organizations and managers will do what's right, act in their best interests, and dedicate the required resources."

Adopt an inclusive leadership style that promotes trust

As a recent Gallup perspective paper explains, "Diversity is about whom you hire. Inclusion refers to the extent to which diverse employees are valued, respected, accepted, and encouraged to fully participate in the organization." Thus, inclusiveness should be viewed as the "necessary activating ingredient" to produce a trusting and supportive environment that enables a diverse workforce to reach their full potential.

Employees reflect this sentiment. In a Deloitte survey of more than 1,300 US employees across industries, the majority of respondents indicated inclusion as a top consideration when choosing an employer; plus, a preference for one where leadership demonstrates consistent inclusive behaviors.

Additionally, the Deloitte study found employees highly value the experience of inclusion; thus, organizations need to focus on what an inclusive workplace "feels" like, rather than just what it "looks" like.

What does inclusion feel like? According to a Catalyst survey, an inclusive atmosphere results in employees feeling "valued, trusted, authentic, and psychologically safe at work." Thus, one key characteristic of inclusion is trust. When employees feel trusted, they become influencers and contribute meaningful feedback to decision-making processes within the organization.

While organizations have an obligation to set the expectations for an inclusive workplace culture, managers should not underestimate the influence they have on fostering this inclusion and building trust. In fact,

the Catalyst study found nearly half of the respondents' inclusion experiences were attributable to having managers who exhibited inclusive leadership behaviors. Managers can adopt an inclusive leadership style that promotes trust through their actions, such as making fair workplace decisions, fostering open communication, and amplifying the voices of team members.

It's also critical to evaluate how your management style impacts team dynamics and promotes fairness and mutual respect. Specifically, an autocratic management style—characterized by micromanaging and policing tone and behavior—signals a lack of trust in team members. An inclusive culture is built upon autonomy and self-directed teams. Thus, managers are responsible for setting the vision and strategy, connecting people to resources, and reinforcing accountability. Then, it's up to the team to take ownership and make the tactical decisions. This autonomy also enables flexibility in work-life balance because employees are trusted to get their work done on their own schedules.

Make fair workplace decisions

We all make assumptions about people of other group identities based on our own cultures and life experiences. Implicit (or unconscious) bias is even more ominous because it occurs automatically and can be harder to mitigate.

For example, social psychology research indicates we make judgements about who to trust within milliseconds based on facial structure, and these split-second decisions can have lasting repercussions (e.g., who we hire). Thus, building trust in work relationships starts during the first interactions with employees.

Managers can take proactive steps to interrupt biased behaviors and increase trust by implementing fair policies and effective organizational structures. Deloitte

says one key area to focus on is employment decisions—hiring, pay, work assignments—because perceived biases in these processes will inevitably destroy trust and demoralize employees. Both The Avarna Group and the National Institutes of Health's Scientific Workforce Diversity Office have developed toolkits on reducing bias in recruitment and hiring.

Foster open communication

An inclusive culture also requires open communication and transparency to develop trusting relationships. With increasing use of virtual communications, we all may feel more socially awkward now, so practicing interpersonal skills (e.g., active listening, role playing) is a worthwhile investment. Adopting an open-door policy also lets employees know they can candidly approach you with both personal and professional challenges, while setting clear boundaries (e.g., what is and isn't appropriate to share) as necessary.

Additionally, direct reports may confide in you about difficult workplace relationships. It's important to ask questions, learn more about the situation, and guide employees in finding solutions to resolve any conflict, instead of taking premature actions that could breach trust or worsen the situation. However, issues related to toxic and harmful behaviors (harassment) need to be addressed immediately to ensure employee safety and trust in the organization to take such complaints seriously.

Also, navigating the difficult conversations around diversity issues requires careful attention to individual sensitivities, while accepting a certain level of discomfort. Gallup emphasizes managers can create trust by facilitating these conversations with compassion and transparency. One useful tool is a community agreement, which develops group consensus on a set of guidelines and acceptable boundaries when engaging in challenging discussions. Such agreements can ensure more productive conversations overall because employees feel more comfortable speaking in a safe and trusting space.

Amplify the voices of team members

The Gallup paper points out there is a certain level of uncertainty and vulnerability that comes from differences, and trust is key for employees to feel empowered to fully participate. It takes much courage for employees from marginalized groups to be their authentic self at work and risk being judged or stereotyped negatively. Managers can thus model inclusive behavior by striving for authenticity, which includes admitting mistakes, being open to feedback, and always learning. By showing your vulnerabilities and a willingness to improve, employees will be more trusting that their differences will be accepted and appreciated.

Another strategy is to amplify the voices of those typically underrepresented in your organization. It's important for employees to be heard and acknowledged to positively reinforce the message that they are valued, respected, and trusted members of your team. Gallup says, "We all have a voice. Encouraging your employees to use theirs will help you create an environment of respect and trust—one full of belongingness, strengths, and engagement." As examples, you can pay attention to who is not being heard from or present at meetings, then actively invite them into the conversation, and track who contributed which ideas to give proper credit.

"By showing your vulnerabilities and a willingness to improve, employees will be more trusting that their differences will be accepted and appreciated."

An additional way to give employees a voice is to create open channels for them to provide continuous and real-time feedback on their perceptions of fairness and trust within the workplace. This approach can also reveal disconnects in perceived trust between managers and their employees to identify further areas of improvement. There are also other institutional assessments, like the Global Diversity, Equity, and Inclusion Benchmarks, that can be conducted to give insight on promoting an inclusive culture.

Overall, by modeling inclusive behaviors and simultaneously building trust, managers can have a lasting impact on diversity and inclusion outcomes within their organizations.

***Donna Kridelbaugh** is a freelance contributor to* Lab Manager.

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An Inclusive Design Process for Breakthrough Research

THOUGHTFUL, CREATIVE LAB DESIGN PRESENTS OPPORTUNITIES FOR ALL LAB STAFF TO WORK AT THEIR HIGHEST LEVEL **by Christiana Moss, FAIA**

The scientific research community is among the most diverse that institutional and corporate organizations serve. Shouldn't laboratory planning, architecture, and design reflect that diversity in ways that are rigorous and highly intentional?

In fact, commitment to inclusion and diversity by research-based organizations can lead to boundary-busting scientific advancement. According to a recent analysis published in *The Journal of Infectious Diseases*,[1] diverse research groups publish more frequently, are cited more often, benefit from complementary skill sets and—in the biomedical and public health fields, in particular—are better equipped to identify and address disparities in their communities across the board. Other studies show that rates of research breakthroughs and achievements accelerate considerably when research teams are composed of the best minds regardless of background, ethnicity, or ability, and when collaboration among principal investigators (PIs) and team members is uninhibited by power dynamics.

Barriers to greater inclusion and diversity are systemic, and as such, are not always obvious to laboratory design teams. Laboratories and their support may not have obvious barriers to inclusion, but in their design and planning, these obstacles do in fact arise for brilliant minds from underrepresented groups. This leads to the loss of their contributions, to the detriment of science. The question, then, is how the goals of diversity, equity, and inclusion should shape laboratory design.

▲ Prior to designing new residential colleges for Washington University in St. Louis, Studio Ma assembled a team to devise engagement tools and capture comprehensive input from undergraduates, grad students, faculty, and staff. The results provided a valuable picture of lived experiences on the Danforth Campus and shaped a plan to address underlying inequities through future design. *Credit: Studio Ma*

> "The key to achieving stated goals for equity and diversity is to reveal the physical and operational elements that trigger feelings of disparity, isolation, or marginalization."

The answer starts with engagement with those who may be impacted. This was the consensus of academic and institutional professionals who gathered virtually for a panel held earlier this year called, "Equity Matters: Campus Planning and Design for Inclusion." While specific challenges varied from campus to campus and from population to population, all agreed that a commitment to studying and fostering inclusion and diversity is itself a major step forward toward true equity on institutional campuses. At Washington University in St. Louis (WashU), Studio Ma recently undertook a large-scale analysis to pinpoint opportunities for continuously improving the experiences of underrepresented students, including in campus facilities. The analysis, which included surveys, focus groups, and

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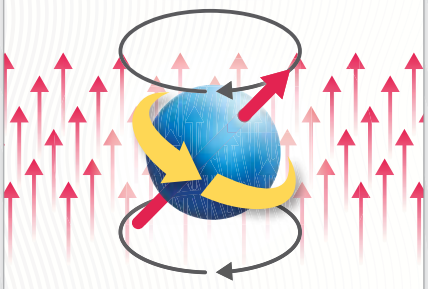
Nuclear Magnetic Resonance Spectroscopy

A powerful technique for analyzing molecular structure

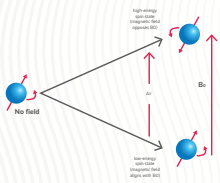
Nuclear magnetic resonance (NMR) spectroscopy is used to determine the molecular structure of a compound. The technique is based on nuclei absorbing energy from a radio-frequency (RF) electromagnetic field when they are immersed in a strong magnetic field.



Principles of NMR Spectroscopy

The NMR phenomenon is based on the physical absorption and re-emission of electromagnetic radiation, which occurs at a characteristic and specific resonance, as is a property of the magnetic nature of a particular atomic nucleus and the intensity of the applied magnetic field. [1]

Nuclei with even numbers of protons and neutrons have no overall spin, however, those with an odd number of protons and/or neutrons possess an overall spin and are referred to as spin- or NMR-active nuclei. Of these nuclei, those with an odd number of protons **and** an odd number of neutrons have integer spins, and those with an odd number of protons **or** an odd number of neutrons have half-integer spins (the most frequently measured nuclei are ^{1}H and ^{13}C).



To achieve NMR:

1. An external magnetic field (B_0) is applied to align (polarize) the magnetic nuclear spins
2. An RF electromagnetic field is applied (often an RF pulse) to perturb the nuclear spin alignment
3. NMR spectroscopy measures the resultant response from the magnetization of the nuclear spins in a sample

In the presence of an external magnetic field two spin states exist: + ½ and – ½, and the gap between them is referred to as ΔE. As the applied field strength increases, ΔE increases. Applied RF radiation is absorbed when it matches ΔE. The frequency of RF radiation absorbed induces resonance, which creates a peak in the spectrum at that specific frequency.

Information Contained in NMR Spectra

Chemical shift

Chemical shift provides information about the composition of atomic groups in the molecule, such as the number and type of electronic environments in a molecule. Chemical shifts are influenced by deshielding (due to electronegative atoms) and anisotropy (due to magnetic fields generated by π bonds).

Spin-spin coupling

The spin-spin coupling effect is quantified with the coupling constant, *J*. It provides information about adjacent atoms and can establish a spatial relationship between atoms. The spin of one nucleus perturbs (polarizes) the spins of intervening electrons. The energy levels of neighboring magnetic nuclei are perturbed by these electrons.

Relaxation time

Relaxation is the process by which an excited magnetic state returns to its equilibrium distribution. Relaxation time provides information on molecular dynamics, and can be used for spectral assignment and the study of quadrupolar and paramagnetic interactions.

Signal intensity

Signal intensity provides quantitative information, such as atomic ratios within a molecule. This can aid in determining molecular structure, as well as the proportions of various compounds in a mixture. NMR signal intensity is proportional to the molar concentration of the sample.

1. Rhodes, C. J. Magnetic resonance spectroscopy. *Sci. Prog.* **100**, 241–292 (2017).

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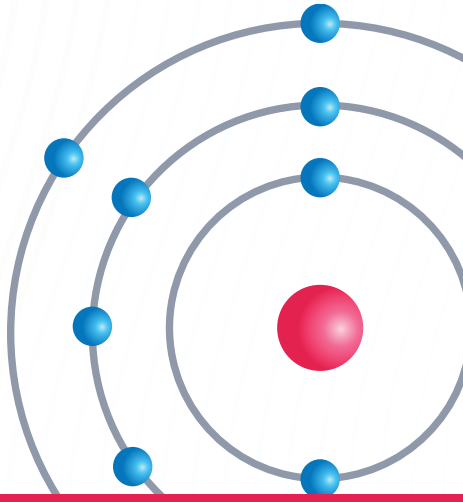
Nuclear Magnetic Resonance Spectroscopy

A powerful technique for analyzing molecular structure



LabManager.com/NMRFundamentals

▲ Conceived within the framework of a student-led design approach, the Memorial Union building at Arizona State University serves 30,000 students daily. The renovated student center now meets needs that were formerly overlooked: study areas for non-residential students, as well as spiritual spaces for underrepresented faiths on campus, such as an ablution room.
Credit: Bill Timmerman, Studio Ma

emotional heat-mapping—a technique for identifying where certain users encounter negative experiences or even barriers to access—revealed real and valuable ways to address these largely solvable challenges through intentional and creative design intervention. *University World News* published the approach.

The upshot: the role of lab managers and their design teams now includes a dimension focused on equity and on creating opportunities for inclusive environments that serve the unique challenges faced by underrepresented lab occupants. To make the medical and scientific research fields more equitable and welcoming, research organizations can follow the lead of universities and engage more broadly in the analyses, engagement techniques, and most importantly, the best design practices that serve to foster diversity, equity, and inclusion (DEI).

Techniques for listening

WashU has found that its DEI efforts are yielding significant and promising results. Over the last five years, the portion of first-year students of color has grown from 12 to 21 percent, with a similar shift in the Pell Grant-eligible population. The results speak, in part, to WashU's efforts to more effectively offer underrepresented students the same campus life experience that traditional students enjoy—in other words, pursuit of equity as a goal has led naturally to greater diversity.

Behind the latest wave of DEI efforts is a focus on campus architecture and planning. The comprehensive studies draw on exacting techniques to establish how underrepresented students react to specific campus buildings and spaces. They also examine operational and physical factors that lie beneath perceptions of inequality.

> "If this level of improvement can be achieved within the organization, then the level of publishable research should increase—and with it, the rate of breakthrough discovery."

Utilizing town halls, focus groups, and live polling to collect ideas for improvement directly from those student populations, the team—led by WashU's then-vice chancellor for student affairs, Dr. Lori White—accessed valuable student feedback. Another method called emotional heat mapping involved tasking students to apply emotional labels on a scale to various campus zones and buildings. Scales might range from unsafe to safe, or from "annoyance" to "joy." The team gathered data in real time through a mobile app that allowed tracking of student geolocations to be linked to emotional responses.

The comprehensive picture that emerged of the emotional landscapes of the campus revealed target areas that could benefit from design intervention. Perhaps unsurprisingly, many students from underrepresented groups recommended giving attention to health care services,

which they felt suffered from issues of access. The study indicated several such key disparities on the physical campus, and students also suggested that improvements to orientation and wayfinding programs were needed.

At the core, this approach is about listening to the impacted individuals. Institutions and organizations can leave emotional heat mapping apps aside and concentrate on surveys and focus groups. Where the organization may lack the skill sets needed to conduct this kind of engagement, consultant groups are available—including many design and planning firms with specialisms in laboratory programming and experience with client-community engagement.

The day-to-day experiences matter

The key to achieving stated goals for equity and diversity is to reveal the physical and operational elements that trigger feelings of disparity, isolation, or marginalization. It is critical to consider the holistic view of the experience of members of the research team, and not just their time spent performing benchwork. This means considering everything including the commute to and from the research facility, the interactions with security, and the architecture of amenities, support spaces, and anything else the researcher interacts with over the course of the working day. Collecting data on the actual experiences of team members will lead to ideas for concrete changes and help to create an environment in which the experiences of individuals from underrepresented communities begin to look and feel more like those of others.

Members of the team who are devout adherents to their faith often encounter challenges related to long hours spent at the research facility, away from the home or the house of worship, where a strict schedule of prayer or other ritual is more easily supported. Solutions for this will vary depending on the campus, facility, and the makeup of the research team, but a fair model for a working approach can be found at Arizona State University's Tempe campus in the recently reimagined Student Union. The facility now features "spiritual zones"—small spaces that provide support for students of faith. These include a meditation room for various kinds of prayer and an ablution room where Muslim students can perform ritual acts of washing before prayer.

Organizational leaders should also be mindful that the experiences of African American and BIPOC (Black, Indigenous, and People of Color) team members may echo their experiences within highly segregated cities and communities. Physical security measures employed to protect sensitive and proprietary research may present unintended barriers to researchers of color, or otherwise may induce feelings of exclusion or anxiety by some who see security checkpoints as a means to keep people from certain backgrounds and groups from gaining entry to the campus or facility.

Within the laboratory space itself, issues of equal access will certainly pertain with respect to researchers with disabilities. Keeping in mind that not all disabilities are apparent at a glance; the same process of engagement and listening is key to making correct decisions before addressing accessibility through design. Harvard University's Culture Lab is currently undertaking a pilot project titled Universal Design for Inclusive Research Labs, aiming to "increase the number of undergraduate students with disabilities in research labs and increase the implementation of Universal Design principles in existing and new research environments." The program may provide valuable insights for various kinds of organizations striving for inclusion and equity.

The ideal research team

Keep in mind that the overarching goal is facilitating and accelerating scientific advancement. The process of engaging with and listening to team members is partly intended to improve their experience directly, but crucially, the organization should be thinking about creating an environment that draws a more diverse recruitment pool. The WashU undertaking described earlier resulted in increased diversity within the student population from 12 to 21 percent. If this level of improvement can be achieved within the organization, then the level of publishable research should increase—and with it, the rate of breakthrough discovery.

Whatever changes organizations make, the input from researchers in underrepresented demographics should provide the roadmap that facilities and planning projects follow, with guidance from careful analysis performed by leadership in consultation with architectural professionals and other relevant consultants. Keeping an ear to the ever-changing needs of underrepresented communities, evidence shows, is the best path forward to achieving an adequately diverse team—which, in turn, should yield significant improvements in performance.

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***Christiana Moss**, FAIA, is principal and cofounder of Studio Ma in Phoenix, AZ.*

Preparing for a Health and Safety Compliance Audit

A STEP-BY-STEP GUIDE FOR THE SAFETY AUDIT PROCESS AND HOW TO BE PREPARED **by Vince McLeod**

Today's modern research laboratories are complex operations with many health and safety challenges. A phalanx of biological, chemical, and physical hazards is faced each day. Equipment such as autosamplers, autoclaves, gas chromatographs, sonicators, vacuum pumps, etc. present unique potential hazards. During a normal, hectic workday, employee health and safety can sometimes get overlooked—and sometimes consequences are grim.

This article intends to prepare the lab manager for a health and safety audit. The basic Occupational Safety and Health Administration (OSHA) regulations and programs will be covered, addressing recognized hazards in the typical research lab. With these tips, lab leaders can better identify and minimize the most common hazards associated with running a busy research laboratory.

Always provide a safe work environment

The OSHA requirement that employers provide a workplace "free from recognized hazards" is the foremost tenet of worker safety. This is known as the "general duty clause," Section 5(a)(1) of the OSH Act, which covers all recognizable hazards, especially those for which specific standards may not exist. Examples of the latter include ergonomic issues and exposures to anesthetic gases or experimental drugs, among others.

Many specific OSHA standards apply to research laboratories. The two most notable within 29 CFR are the occupational exposure to hazardous chemicals in laboratories, also known as the OSHA Lab Standard (1910.1450)[1], and hazard communication (1910.1200).[2] Other standards that might apply include respiratory protection (1910.134), electrical and fire safety, and those dealing with certain toxic and dangerous chemicals such as benzene, methylene chloride, etc.

Entrance and pre-audit conference

When first approaching any area that may contain hazards, lab professionals should recognize that the room they are about to enter is different. It is not an office. There are things that set this area apart and have the potential to harm or injure. So, all entrances should have complete and proper signage to alert anyone planning to enter to the hazards within.

Signs should indicate if chemical hazards are present—and if so, what type. Corrosive, toxic, flammable, carcinogenic, and other signs, as appropriate, should be posted on or near the entrance door. Also, be sure to include emergency contact information and names and phone numbers for the principal investigator (PI) and laboratory manager, at a minimum.

Upon entry, most auditors will ask to see the lab's chemical inventory, chemical hygiene plan (CHP), and standard operation procedures (SOPs). Training records and source(s) of safety data sheets (SDS) may also be requested. After perusing the inventory and SOPs, the auditor, especially if unfamiliar with the lab, might ask for a brief tour and description of the basic lab operations and work areas.

The survey or walk-about

Following the pre-audit conference, the auditor will begin the health and safety survey, or walk-about. Protecting

worker health and safety begins with recognizing workplace hazards. Generally, these fall into three main categories: chemical, biological, or physical. Examples of chemical hazards include corrosive chemicals, solvents, cleaning agents and disinfectants, drugs, anesthetic gases, paints, and compressed gases. Potential exposures to chemical hazards can occur during handling, use, transport, or storage.

Biological hazards are usually limited to specialty labs and include potential exposures to allergens, zoonotic diseases (animal diseases transmissible to humans), and experimental agents such as viral vectors. Allergens, ubiquitous in animal research facilities, are one of the most common, yet frequently overlooked, health hazards.

Physical hazards are always present in laboratories and research facilities. The most obvious are slips and falls from working in wet locations and the ergonomic hazards of lifting, pushing, pulling, and repetitive tasks. Other physical hazards that are often unnoticed include electrical, mechanical, acoustic, or thermal hazards.

Focusing on the most common hazards

The number one hazard in labs—chemical misuse or mishandling—provides the potential for significant harm or injury. Auditors will usually zero in on areas of chemical use and storage. To avoid problems, be sure to have and implement a robust chemical control and handling program.

The OSHA standard that helps mitigate these potential problems is the Hazard Communication Standard, which deals with employers' requirements to inform and train employees on the use of chemicals. In addition, the OSHA Lab Standard, 29CFR1910.1450, requires laboratories to identify hazards, determine employee exposures, and develop a CHP. The "lab standard" mandates written SOPs addressing the particular hazards and precautions required for safe use. Both standards require maintaining SDS and providing employee training.

Number two on most auditors' lists would cover physical hazards. The inherent, significant physical

hazards present include electrical safety hazards, ergonomic hazards associated with manual material handling and equipment use, handling sharps, and basic housekeeping issues.

Check for proper usage of extension cords and an easily accessible and well-labeled circuit breaker panel, for starters. Equip all electrical power outlets in wet locations (outlets within six feet of a sink, faucet, or other water source) with ground fault circuit interrupters, or GFCIs, to prevent accidental electrocutions. Do not substitute flexible extension cords for permanent wiring. Ensure all cord insulation is in good condition without cracks, breaks, cuts, or tears. Take care to not run extension cords through doors or windows, where they can become pinched or cut. Use only grounded equipment and tools with grounding pins present, and always be aware of potential tripping hazards when using them.

Review all laboratory operations that necessitate workers performing sustained or repetitive motions. Conduct an ergonomic work survey, and ensure a neutral, balanced posture for these tasks.

Use only puncture-proof and leak-proof sharps containers that are clearly labeled. Train employees never to remove the covers or attempt to transfer the contents. Make sure they get replaced when three-fourths full to prevent overfilling.

Finally, do not overlook general housekeeping. Slips, trips, and falls are very common, yet easily avoided with safe and organized storage areas. Store materials in tiers stacked, blocked, interlocked, and limited in height so that they are stable and secure against falling or collapse.

Specialty biological labs entail hazards with infectious microbes, recombinant organisms, and viral vectors. Much of the work with recombinant DNA, acute toxins, and select agents is now regulated by federal agencies such as the US Department of Agriculture, the Department of Homeland Security, and the Department of Health and Human Services, including the National Institutes of Health. If your facility is conducting research in these areas, you should have an institutional biosafety committee to keep everything in order and running smoothly.

The most prevalent biological hazard, in terms of frequency of occurrence, is exposure to allergens associated with the use and care of laboratory animals.[3] Health surveys of people working with laboratory animals show that up to 56 percent are affected by animal-related allergies. Health and safety issues should address containment, the ability for replication, and potential biological effect.

Post-audit conference

The health and safety audit should usually end with a post-audit conference. The auditor reviews all issues with the PI or manager and discusses appropriate corrective actions and a timeline for completion. A written summary is transmitted shortly after the visit and should include the agreed upon corrections and completion dates. A follow-up visit should be performed to ensure corrective actions are finished.

> "Protecting worker health and safety begins with recognizing workplace hazards."

Research laboratories present many health and safety challenges. However, with proper guidance, a trained eye, and practice in conducting in-house audits, laboratory leaders can find and correct many common mistakes and prevent illness or injury.

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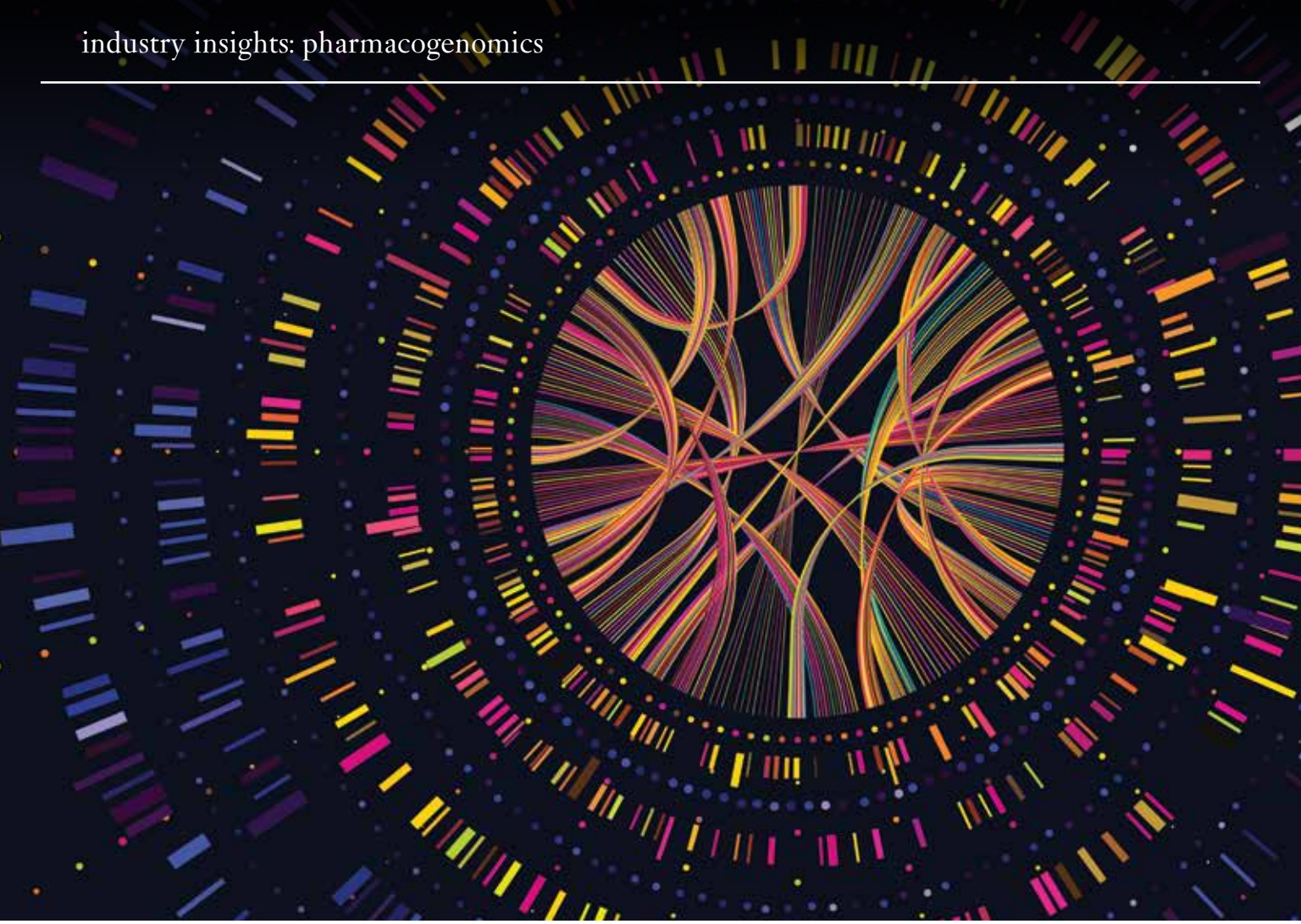

The Importance of Diversity in Pharmacogenomics

PHARMACOGENOMICS IS A POWERFUL TOOL WITH THE POTENTIAL TO ENHANCE PRECISION MEDICINE **by Clinton Harmon**

With nearly eight billion people on our planet, it should come as no surprise that humanity is as complex as it is diverse, especially when it comes to our genetic information. Unfortunately, this diversity can lead to disparities in health care that can be difficult to account for.

Researchers in the budding field of pharmacogenomics have made extensive efforts to understand these disparities. While many cultural and lifestyle causes have been identified, genetic variation seems to offer the most effective explanation. So, what happens when pharmacogenomic studies do not accurately represent the scope of global genetic diversity?

Pharmacogenomics is the study of how genes affect an individual's response to pharmaceutical drugs, combining the fields of pharmacology and genomics to develop medical practices that are safe, effective, and uniquely tailored to an individual—known as precision medicine. From finding the right pharmaceutical to determining the proper dose, our genetic information is the key to

understanding how medicines function within us—a patient may break down a drug too slowly, too quickly, be non-responsive, or experience potentially fatal side-effects. Understanding the genetic background of a patient can help determine if a drug is safe and effective before the first dose is even administered.

In theory, the most effective way to understand the pharmacogenomics of an individual would be to sequence and compare the genomes of the entire population on Earth to look for genetic variants that are associated with various diseases. Unfortunately, sequencing every genome on the planet would be cost-prohibitive and logistically impossible. Scientists have overcome this hurdle by using techniques that can analyze many individuals' genomes and compare them across different cultural, racial, or ancestral populations.

> "This Euro-centric bias can have dire consequences for clinical health care, resulting in medical practice that is incomplete, ineffective, or even mistaken."

Genome-wide association studies (GWAS) are one of the most prevalent techniques used to conduct genomic medical research, as they scan the genome of many individuals for genetic variants that may be associated with certain diseases. A typical GWAS utilizes single-nucleotide polymorphism (SNP) arrays to identify possible variants. However, there has been growing pushback against using SNP arrays in favor of whole-genome sequencing (WGS) as it provides more complete genomic data.

For example, SNP arrays can only associate diseases with known variants, making them particularly susceptible to association bias. An SNP array looks only at previously identified SNP loci within a genome to find variation, meaning these arrays are not effective for discovering novel or rare variants. However, as WGS creates a complete set of genetic data, it has the potential to discover all genetic variants—especially rare variants—making WGS a more powerful and unbiased tool than SNP arrays for the identification of genetic risk factors. Even still, SNP arrays are widely used due to their reliability, low cost, and maturity of the data processing technology—the opposite of which is true for WGS. Fortunately, it is expected that as the cost of WGS reduces, the prevalence will increase.

Regardless of the techniques used, GWAS come with some limitations. GWAS are inherently geared toward establishing an association and not a causal link between a variant and disease. To establish a causal link, post-GWAS techniques such as statistical fine-mapping are often required. Fine-mapping attempts to take a trait-associated region or SNP from a GWAS and analyze it to identify candidate genetic variants that may have a causal link to disease. These candidates can then be further studied through laboratory-based functional experimentation to confirm any causal links.

As with any genomic studies, GWAS can only analyze a limited slice of humanity, so it is imperative that they adequately represent the global genetic diversity to obtain unbiased extrapolations of the genome's effect on disease. Unfortunately, most research within genomic study has not reflected this diversity.

PHARMACOGENOMICS LACKS DIVERSITY

The bulk of research in pharmacogenomics displays an alarmingly disproportionate amount of people of European descent, despite the overwhelming majority of genetic variation stemming from people of non-European descent, particularly African.

This Euro-centric bias can have dire consequences for clinical health care, resulting in medical practice that is incomplete, ineffective, or even mistaken. If a study only focuses on the European population and disregards the majority of global genetic variance, the data may only be relevant for those of European descent. This misrepresentation of diversity harms individuals of under-represented ancestries by weakening or destroying any clinical utility that pharmacogenomic findings may offer through sub-optimal disease prediction, diagnoses, or treatment.

Due to this, there has been concern regarding the replicability of the genetic variant associations across different genetic populations found in many GWAS.

In a recent interview, Minoli Perera, an associate professor of pharmacology at Northwestern University, highlights the dangers that a lack of diversity in

pharmacogenomic research poses to medical care, particularly in people of African descent. In her example, she highlights two gene variants that are heavily associated with the pharmaceutical warfarin. While she acknowledges their clinical utility in diagnoses, her research team discovered that these variants are far less sensitive when determining the dose-response of warfarin in people of African descent—a fact that was obscured due to a historically woeful misrepresentation of African Americans in these GWAS. Through the use of a more representative GWAS, her team identified additional gene variants that accounted for this variability in dose-response. Minoli's research group was just one of numerous other groups to identify the genetic disparity between warfarin-associated variants that were only present in people of African descent.

Warfarin is not the only example of adverse drug reactions due to genetic variability associated with geographic ancestry. Evidence has shown that more inclusive research often identifies novel or rare genetic variants that are more clinically relevant for precision medicine. Examples such as these highlight the need for an accurate and complete understanding of a patient's ancestry and ethnicity to better anticipate what genetic variants may be present when creating a treatment plan.

A HOPEFUL FUTURE

Though fast-growing, the field of pharmacogenomics is relatively new. As such, there have only been a handful of pharmaceutical successes tied to genomic study, but as knowledge of genomic diversity grows, so too will pharmacogenomics and precision medicine. In short, inclusion is the name of the game for ensuring effective and clinically relevant medicine, even if this may be easier said than done.

Alice Popejoy, a researcher at Stanford University School of Medicine, noted that the solutions to the lack of diversity in genomic studies involve "ideological, analytic, cultural, demographic, and systemic elements," and adds that "researchers must commit to broader inclusion of diverse study participants and mentorship of underrepresented trainees from the bottom-up, and institutions must facilitate the development of a diverse knowledge base and workforce from the top-down."

Researchers like Popejoy make it clear that continued efforts must be made that account for global genomic diversity if research is to obtain more complete data for more effective treatments in underrepresented populations. Logistic elements such as funding, training, and clinical recruitment must increase while systemic practices that perpetuate a Euro-centric bias in genomics research must be quelled.

To this end, researchers can look toward the efforts of research initiatives such as the Population Architecture using Genomics and Epidemiology, Phase II (PAGE II), which developed the Multi-Ethnic Genotyping Array (MEGA) to increase variant coverage across multiple ethnicities. Another option is the Human Heredity and Health in Africa (H3Africa), a consortium that developed a pan-African genotyping array for the express purpose of building a greater capacity for genetic research in Africa and driving novel research in genetic variance.

"Evidence has shown that more inclusive research often identifies novel or rare genetic variants that are more clinically relevant for precision medicine."

Unfortunately, genome-wide arrays such as these are used infrequently due to high costs and the relative novelty of the technology; instead relying on targeted genotyping arrays that use SNPs discovered using subjects of European ancestry.

If researchers are to combat the flagrant Euro-centric bias and increase the clinical utility of pharmacogenomics for people across the globe, genome-wide arrays like MEGA or H3Africa must be increasingly prevalent.

The birth of pharmacogenomics in the early 2000s promised a hopeful future, yet almost two decades later it is clear that this hopeful future has been marred by a fundamental bias. Fortunately, this bias has been recognized and efforts are being made to correct the misguided course. Researchers are beginning to understand that our genetic differences must be accounted for if pharmacogenomics is to guide the future of precision medicine.

Clinton Harmon is a science writer and editor with an MS in Biotechnology and Genomics from Texas Tech University.

Lab Startups

A GUIDE BEFORE YOU BEGIN

Q

So, you're changing your lab, expanding, or opening a new one?

Congratulations. But now you're starting to realize there's lots to do. Without a plan and proper support, it can be a daunting task. Not only understanding which boxes to check, but which lists to write can be overwhelming. Lab funding isn't endless, and a bad financial decision could stall your research and career progress. Whether you're starting from ground zero or moving to a new space, setting up your lab the right way, the first time, is crucial to streamlined functioning and future expansion.

A

Asking the right questions early on is one of the crucial steps to success.

Building a checklist and knowing what questions to ask will get you off to a good start. Get thinking about infrastructure, equipment and instrumentation, as well as the protocols to have in place and support for your people and ongoing maintenance. Shortlist and engage the right vendors, who can help you with grant-matching and big discounts on the kit you'll need as well as supporting you to optimize your lab space and ask questions you haven't thought of yet. Read this helpful guide before you begin, and start your lab startup journey.

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Venu Vandavasi, PhD

ASK THE EXPERT

TECHNOLOGY AND TRENDS IN BIOPHYSICAL CHARACTERIZATION

by Tanuja Koppal, PhD

Venu Vandavasi, PhD, director of the Biophysics Core Facility in the Frick Chemistry Laboratory at Princeton University, talks to contributing editor Tanuja Koppal, PhD, about the changes he is witnessing in the technology and applications for biophysical characterization of molecules. He also discusses the current challenges and what can be done to mitigate some of them.

Q: Can you tell us about your work and the types of techniques you use in your biophysics core facility?

A: Our core facility houses a wide variety of techniques to help with the biophysical characterization of diverse molecules. We use analytical ultracentrifugation, biolayer interferometry, circular dichroism spectroscopy, differential scanning calorimetry, dynamic light scattering, isothermal titration calorimetry, fluorescence spectroscopy, microscale thermophoresis, surface plasmon resonance, and more. The biophysical interactions that we study involve molecules such as proteins, nucleic acids (DNA and RNA), small molecules, and lipids. The small molecules include synthetic chemicals and drug-like molecules or peptides that are extracted from living organisms or synthesized in a lab. We also work with proteins, DNA, and RNA that are labeled with various chemical tags.

Our users want to study how these molecules interact, and we characterize them both qualitatively and quantitatively. In qualitative analysis, we find out if these molecules are interacting or binding with each other. For quantitative analysis, we evaluate how strongly they are interacting and determine the affinities of binding. Further, we characterize the thermodynamic parameters and kinetics of these interactions, or sometimes, we study the secondary or tertiary structure of proteins and changes in the structure caused by these interactions, which is often important for their function. We also study the oligomeric states of biological molecules and how they are affected by other molecules.

> "Advances in synthetic chemistry have made it possible to have huge libraries of small molecules."

Q: What are some of the main trends that you are seeing in biophysical analysis, in terms of technology and applications?

A: Biophysics core facilities have equipment that use the principles of math, physics, and chemistry to characterize biological molecules and address biological problems. These instruments tend to be quite expensive and require technical expertise. The lifespan of these instruments in a core facility is about five to six years, by which time they either start to break down or a new technology comes along to replace it. Some of these techniques have been in existence for about 50 years, but access to these instruments has been quite limited until about 10 years ago, when core facilities were set up to share resources. The biophysics core at Princeton University was established and started its operations in 2018.

Previously, the applications of these biophysical techniques were mostly related to basic science projects. However, in recent years the projects have moved toward applied research, and in the past year many of them were related to COVID-19. Advances in synthetic chemistry have made it possible to have huge libraries of small molecules. Biophysical screening of these molecules against drug targets (proteins or nucleic acids) helps determine which of these molecules

have potential to be new therapeutic drugs. These potential molecules are called "hits." Similarly, with advances in biology, new drug targets are being discovered and screened to identify which ones are "druggable." The hits need to be analyzed and characterized in detail to understand what kind of drug-target interactions are taking place. What is the kinetics of those interactions? How will it affect the structure and stability of the bio molecule? Answering each of these questions needs a different technique and we have them available in our biophysics core. Automation of the instrumentation and advances in the software have saved a lot of time for performing experiments and made it simpler to analyze the data.

Q: What are some of the big challenges in biophysical characterization today?

A: The core facilities typically house many different types of instruments and the lab managers need to have a good understanding of their strengths and limitations. Knowing which technique is appropriate to address a certain biological problem is never easy. The rationale for picking the right technique is subjective, given many different techniques can give similar or same answers at times, and this comes with experience and thorough knowledge of what each of them has to offer. Keeping up to date with the new technologies is always challenging. To understand the instrumentation, you must have a good understanding of the math, physics, and chemistry, but the problems you are dealing with are biological and that needs a good understanding of the biological context as well. Each biomolecule is different, and each problem is different.

The other big challenge is managing the quality of the sample that comes in for testing. We always suggest some pilot experiments and quality control tests be done to ensure that samples are good. We have techniques that help users quickly determine the sample purity and concentrations before they conduct a laborious and time-consuming experiment. For core facilities that function as a contract research organization, things are streamlined, automated, and mostly done by trained personnel. However, in an academic setting, a lot of decisions must be made in real time. We train about a few hundred students every year with different levels of expertise and scientific backgrounds, and they run their own experiments while we provide consultation and help troubleshoot issues with instrumentation. This can be a challenge because each one handles the instrument differently. While we can predict the lifespan of an instrument, it is not always accurate due to user variability. Hence, there are always challenges with maintenance of the instruments and getting funding.

In terms of investing in new techniques, the objective must be very clear, and the equipment should sustain its own running cost. Be up to date with the technologies and follow the trend in high impact journals to see what techniques the scientists are using. Avoid buying expensive instruments that will appeal only to a small group of users. If you do buy a very expensive instrument, be prepared to have to do some of the work yourself. For a core lab, it is always a good idea to consider which instrument can make things simple and reduce the time for analysis.

Venu Vandavasi obtained his PhD in Biophysics and Structural Biology from Saha Institute of Nuclear Physics, India, in 2011. He performed his postdoctoral research at the Life Sciences Institute at the University of Michigan, Ann Arbor, and at the Oak Ridge National Laboratory, Oak Ridge, TN. Since 2018, he has led the Biophysics Core Facility at Princeton University and lectures advanced biophysical chemistry at Princeton. He acts as a subject matter expert, provides consultancy, and necessary training to researchers in the areas of biophysics at Princeton. His research interests include biophysics and structural biology of proteins with therapeutic and industrial importance.

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CENTRIFUGES

COMMON ERRORS FOR NOVICE USERS TO AVOID

by Holden Galusha

There are baseline centrifuge usage protocols that every scientist has drilled into their head by the time they begin working in a laboratory, like the foundational "always balance the rotor." Nonetheless, sometimes the details of safe, effective usage can slip between the cracks and leave new users making mistakes that hinder your lab's productivity. Below are three of the most common errors that fresh scientists make when they're learning the ropes of centrifugation.

Neglecting to ask questions

It's common for novice scientists to feel that they must prove their competence in the lab. Unfortunately, the "I can do it myself" mindset often prevents new staff from seeking guidance when they should. These breakdowns in communication can have adverse effects on the lab as a whole.

New users neglecting to ask questions can damage the centrifuge and, in some cases, send the lab's productivity into a tailspin. "If you wreck the centrifuge, which everyone uses, you've shut down that lab for X amount of months, right?" says Luc Roberts, chief scientific officer of Allos Bioscience. To prevent this issue, Roberts recommends fostering an environment of open communication where novice and seasoned professionals alike are comfortable asking for assistance.

Failing to clean up spills

Leaving behind a messy rotor chamber is generally a benign mistake. In some cases, however, the consequences can exceed mere inconvenience. If a user is loading a rotor with biohazardous samples—such as blood—and spills some, then they should immediately clean it up. Otherwise, the health of the next user could be at risk. Hiba Shamma, a lab coordinator at Battelle Organization, has encountered this issue while training new lab staff. "When I give them [new lab staff] orientation, [I tell them] 'Hey, even if you're not doing any Risk Group 1, Risk Group 2 work—even if it's protein work you're doing—you have to decontaminate your area with bleach and isopropanol.'" By establishing a clear, broad procedure for instrument usage, like Shamma and Roberts have in their labs, you can ensure that your newer staff develop the right habits and are less likely to forget proper maintenance.

Visually estimating sample volumes

Although it may be a convenient shortcut, forgoing the use of a high-precision balance and instead estimating sample volume is a bad habit. Because centrifuges amplify mass, even the smallest differences between the fill levels of opposing tubes can, at sufficient speeds, result in unstable spinning. While it's true that modern centrifuges have imbalance detectors to automatically end an unstable run, premature termination can still damage the samples.

It's also worth noting that many laboratories still use older centrifuges that lack these sophisticated safety features. In such cases, it's vital to ensure that a rotor is balanced properly.

While procedural mistakes like forgetting to clean spills or eyeballing a sample volume can happen for plenty of reasons, many of them are caused simply by a weak communication culture. By prioritizing communication, laboratory managers can preemptively address any potential misconceptions and ensure that everyone knows what is expected of them and is comfortable seeking assistance.

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ION CHROMATOGRAPHY

SENSITIVITY AND ACCURACY IN WATER PURITY ANALYSIS

by Brandoch Cook, PhD

What do you think about when you go to the kitchen sink to get a glass of water to drink? Probably nothing much, beyond "I'm thirsty." Incredibly, this nonchalance is a luxury that is less than 50 years old. The fact that we *can* be nonchalant is due in part to the reliability of ion chromatography (IC) as an analytical technique to measure, among other things, inorganic ions in drinking water.

Measurement of inorganic anions in drinking water

There is a long list of inorganic anions that can be detected in drinking water using IC, including chloride, fluoride, sulfate, nitrate, and nitrite. Excess environmental fluoride can cause fluorosis of teeth and bones; water high in sulfate acquires an unpalatable rotten-egg flavor and smell; and chloride ions can react in solution with particulates to generate oxyhalides. Additionally, chlorination and ozonation can generate dangerous trihalomethanes and bromates. Nitrate and nitrite are particularly dangerous for infants susceptible to hematological defects. The maximum containment level (MCL) standards are unique for each anion, with milligram-per-liter levels acceptable for some comparatively innocuous ones, and MCLs in the low microgram-per-liter range for putative carcinogens. Innovation in column and instrument design is driven in part by progressively tighter environmental and health standards. As MCLs decrease, greater sensitivity in measurement is required.

A standard IC instrument consists stereotypically of guard, separator, and analytical columns, a suppressor device, and a conductivity detector cell linked to a mass spectrometric readout. The choice of column material and particle size, and of eluent composition, contributes to accuracy and reproducibility, while a suppressor supplies additional sensitivity. For anion detection, a suppressor commonly uses a high-capacity cation exchange column to replace eluent cations with hydronium. This serves to neutralize a carbonate or hydroxide eluent and impart acidity to analyte ions, giving them artificially high conductivity and therefore greater signal-to-noise ratios.

A balance between accuracy and sensitivity

Ion quantification with IC is sometimes a tricky balance between accuracy and sensitivity. The latter can be optimized with appropriate column choice and use of suppressors, while the former is often dependent on proper sample dilution and filtration, and general good housekeeping where instrument and reagent use and maintenance are concerned.

Suppressed conductivity measurements for bromate in trace amounts can be artificially amplified and inconsistent, whereas for a common ion such as chloride, suppression can force measurements outside of linear ranges established by instrument calibration.

> "Ion quantification with IC is sometimes a tricky balance between accuracy and sensitivity."

A reliable strategy is to select elution reagents and column types to optimize the expected analyte retention time, favoring preliminary elution of unwanted anions preparatory to obtaining the desired one. For instance, detection of fluoride, chloride, or sulfate ions can each be accomplished with sodium carbonate eluents and separation column particle sizes in the four-to-10-micron range. However, the peak elution range of fluoride notoriously coincides with many extraneous ions that are shed from the column, resulting in interference problems. Chloride ions are often present even in deionized reagent water certified with 18-megaohm resistance, providing another source of interference. Moreover, reagent water

often contains high levels of total organic carbon (TOC), which can elute in carbonate streams and alter conductivity, resulting in broad and confounding MS peaks. Finally, trace cations can cause precipitation of hydroxides in basic solutions and in water before it is equilibrated to neutral pH.

A primary solution to interference or contamination is to be assiduous about preparation of reagents and standards. For measurements to be reproducible, standard curves for analytes of known concentration are required prior to sample testing. Therefore, users must maintain highly pure reagent water, which can be vacuum-filtered and degassed to eliminate contaminating ions and TOC. Additionally, one can implement acidic gradients in which a slight decrease in pH from standards to analytes will tighten detection peaks; nitric acid is often a good substitute for water in the mobile phase. Contemporary instrumentation often maintains inline ultrafiltration systems that aid in sample preparation by removing excess particulates that can interfere with analyte quantification. Similarly, proper sample dilution can be programmed into workflows to ensure that resulting detection levels remain within a linear range compared to standards. In this way, one can take maximum advantage of a venerable and reliable platform for ion quantification.

Clean water for people and industry

The Safe Drinking Water Act and the Clean Water Act precipitated a system of regulations governing impurities in drinking, surface, and ground water, and capping allowable discharges in wastewater. Cations and inorganic anions comprise many of these impurities, and each has intrinsic conductivity in solution. IC can leverage this conductivity to partition ions of interest across exchange columns, allowing ions to be specifically eluted and quantified using pH changes and other indicators of varied conductance. In the 1980s, the Environmental Protection Agency (EPA) introduced the IC-based Method 300.0 to measure inorganic anions and disinfection byproducts in drinking water, and in 1997 updated it to Method 300.1, which still applies today. The EPA publishes and enforces analogous methods for determination of cation levels, impurities in ground and surface water, and constituents of effluent wastewater.

The intent is to protect human consumers from toxicity; however, industrial processes such as oil and gas refinement, paper production, polymer, and microchip manufacture all require vast quantities of ultrapure water or steam. Given the large volumes, and attendant issues of cost and sustainability, industrial process water must often be repeatedly recycled through facilities before being discarded as waste. Source water can contain scaling ions such as silica, calcium, and magnesium; and corrosive anions including chloride, fluoride, and sulfate. Chemical deionization before use, and filtration and decontamination preparatory to recycling or discharge, can reveal and introduce indicators and inhibitors of corrosion, which must be removed at alternating points in production cycles. Wastes, improperly handled, can contribute to some of the most devastating and inter-generational environmental hazards experienced by our society. Mitigation is dependent on changes in policy, but these can be enforced and improved most effectively by starting with accurate and sensitive measurement via ion chromatography.

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MOISTURE ANALYZERS

CONTROLLING WATER CONTENT HAS BROAD INDUSTRIAL APPLICATIONS

by Andy Tay, PhD

Controlling water content is essential in many biological and chemical applications, including food, pharmaceuticals, and hydrocarbon processing. A moisture analyzer is used to quantify water content. However, depending on the state (solid, liquid, or gas) of the samples, different methods are required. In this article, we will explore the use of moisture analyzers for various quality control applications.

Food and agriculture

Moisture control in food is critical because too much moisture may promote growth of harmful microbes, while too little moisture may affect the consistency and taste of the food.

The water content in solid or semi-solid food can be measured using moisture analyzers with the loss on drying method. In this method, the sample is weighed, dried, and weighed again. The difference in weight is the mass of water. This is achieved by moisture analyzers with a precision electronic balance and a sample tray surrounded by a heating element. The whole process can be automated and with the use of a microprocessor, heating can occur rapidly and uniformly.

Pharmaceuticals

Pharmaceutical companies have to ensure consistent products. Drugs in the form of pills will agglomerate or lose their bioactivity with too much moisture. With too little moisture, they may lose their shape and form. Karl Fischer coulometry is commonly used for pharmaceutical applications. It involves the conversion of solid iodine (black) into hydrogen iodide (colorless) when iodine reacts with water. The reaction finishes when no more water is left. As this reaction is water-dependent, atmospheric humidity could easily affect the results. Hence, the system is usually performed in a container with inert gases like dry nitrogen. Note that Karl Fischer coulometry can also be used for liquid and gas samples. Liquid sample can be injected directly into

the analysis tube or cell while a special setup is needed for gas samples, such as in the petrochemical industry.

Hydrocarbon processing

Moisture analyzers are used in almost all stages of hydrocarbon processing in the oil and gas industry. They are used to analyze water content before natural gas liquid extraction and to detect for trace moisture before liquified natural gas liquefaction. Furthermore, as moisture can affect the performance of refining catalysts, a moisture analyzer is used to prevent catalyst contamination during oil refining. Further downstream, moisture control is essential to petrochemical production (such as polymer and rubber) for quality control of material properties like viscosity.

Due to the precious nature of hydrocarbons, moisture analyzers with hygroscopic quartz crystal are used for more accurate measurements. Based on the differences in vibrational frequency of the quartz crystals and by comparing that to a calibration curve, the water content in the gas sample can be determined.

The water content in samples can be determined by mechanisms involving changes in color, mass, light, and even electrical signals. In addition to the applications discussed, moisture analyzers are used in many other industries such as semiconductors, paper production, and metal processing. This instrument is very helpful to provide quality control to ensure product consistency.

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NMR SPECTROSCOPY

THE USES FOR NMR IN DIAGNOSTICS ARE EXPANDING WITH ADVANCES IN TECHNOLOGY

by Aimee O'Driscoll

Nuclear magnetic resonance (NMR) has long been used in the fields of clinical and academic research. It also has a lengthy history in diagnostics, perhaps most notably for its role in magnetic resonance imaging (MRI). In recent years, the application of NMR in diagnostics is broadening in scope, such that it may be used in other areas in the frontline health care industry.

The benefits afforded by advancing NMR techniques include robust, reproducible results that can provide rapid and accurate information about a variety of diseases. New technologies allow for quick, straightforward, and cost-effective screening for a range of disease markers. Some of the fields in which NMR may be useful include diagnosis of liver disease, kidney disease, neurological disorders, cardiovascular disease, and cancer. In particular, NMR is being more broadly used in metabolomics whereby metabolites are analyzed to more effectively diagnose and treat disease.

Here, we explore the history of NMR in diagnostics and the progress that is being made in the field.

Traditional use of NMR in diagnostics

In NMR spectroscopy, atoms in a constant magnetic field are subjected to radio frequency radiation that forms a second oscillating magnetic field. Upon absorption of radio frequency energy, the phenomenon of NMR causes the nuclei of atoms to resonate. The frequency of this resonance and the resulting electromagnetic signal is characteristic of the magnetic field at the nuclei of atoms.

When detected using an NMR spectrometer, this resonance can help determine the chemical, physical, and biological properties of substances of interest. NMR was first used to assign previously unknown molecular structures in 1955, and is still widely used to determine the structure and identity of molecules. NMR spectroscopy is a hugely useful analytical tool that's utilized in many laboratories across a range of disciplines. Some key uses include investigating the structure of organic molecules and studying molecular physics.

NMR is broadly used in the medical field, and perhaps the most well-known application of NMR is MRI. MRI is a multidimensional imaging technique that uses the NMR phenomenon to create images of parts and processes of the body in medical diagnostic applications.

> "The benefits afforded by advancing NMR techniques include robust, reproducible results that can provide rapid and accurate information about a variety of diseases."

This method is popular for multiple reasons—key advantages being that it is non-invasive and non-destructive. It is highly useful for diagnostic imaging of soft tissues, including the heart, brain, and muscles, and can often be used to discover tumors in various parts of the body. The technique was first developed in the 1970s, with MRI machines becoming commercially available in the 1980s. Now, millions of MRI scans are conducted in the US each year.

NMR is currently advancing the field of diagnostics

While MRI is now a staple in today's world of diagnostics, the research and innovation around NMR techniques doesn't stop there. For example, NMR is very useful in areas of biomedical research such as the study of protein and peptides, as well as individual amino acids and nucleic acids. It can be used to analyze structure, dynamics, and interactions.

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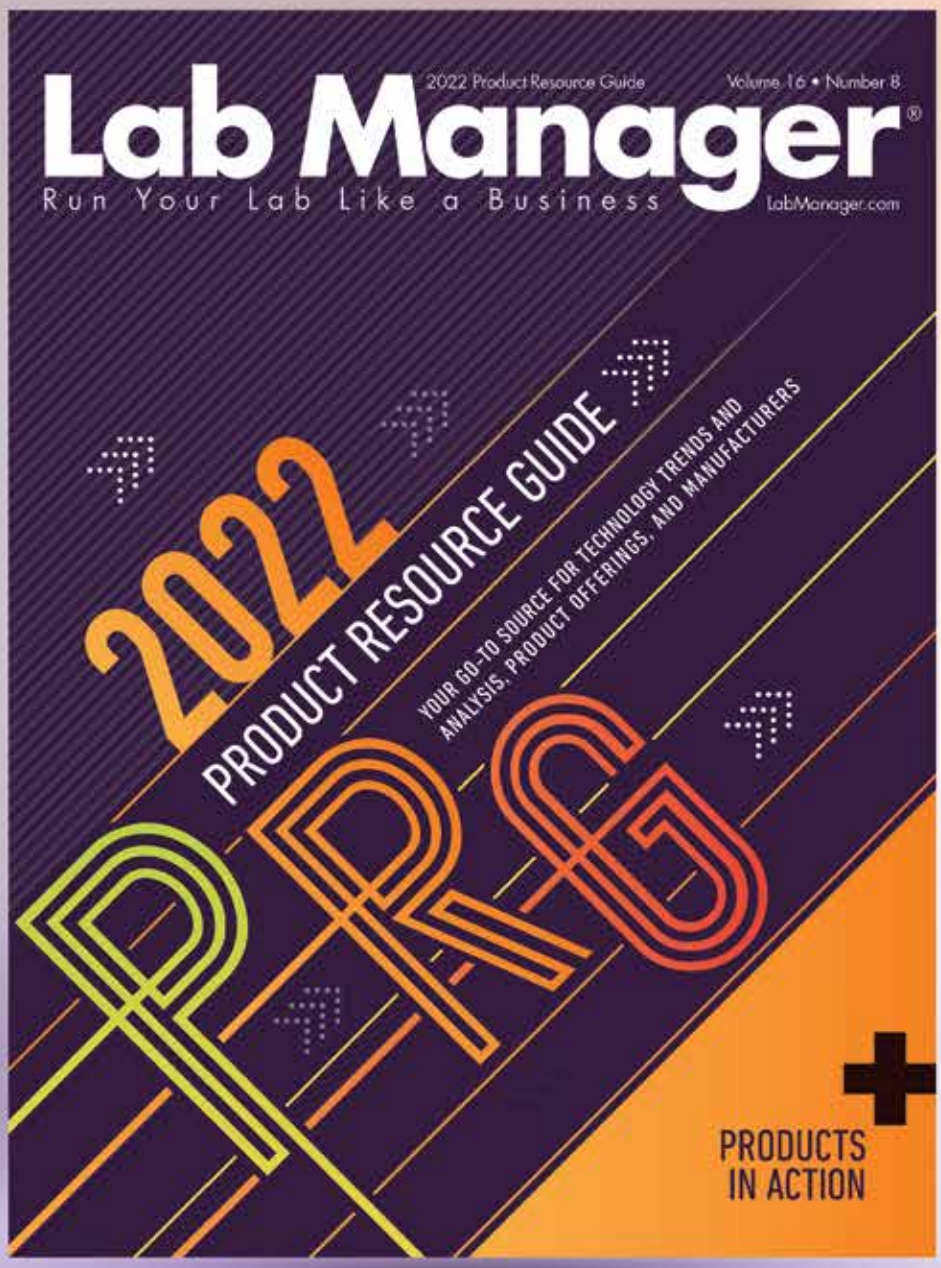

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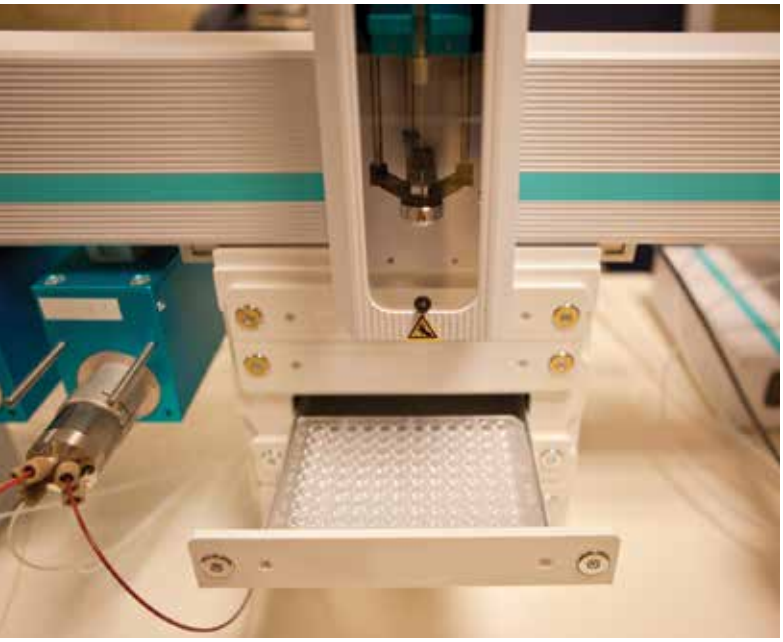

In recent years, NMR has been featured heavily in the area of metabolomics. This rapidly growing field involves the study of metabolites to discover information about diseases. The use of metabolomics has traditionally weighed toward research applications, but there is increasing potential for it to be extremely helpful in laboratory diagnostics. Metabolomics can provide valuable information about downstream products of metabolic and cellular processes, offering insight into the status of certain tissues and organs. NMR spectroscopy is being used successfully to quantify metabolite concentrations in various fluids, including urine, plasma, and serum.

One organization leading the way in this field is numares. This company focuses on metabolomics-based diagnostics used to interpret biomarkers. Together with Bruker, numares is working to deliver NMR-based diagnostics tests to the laboratory market.

The numares platform, branded AXINON®, can provide rapid access to accurate and personalized data pertaining to the progress and severity of the disease being studied. The tests use a high-strength magnetic field in combination with artificial intelligence technology to automate the measurements of metabolites. They analyze clusters of risk factors (referred to as "constellations") as opposed to individual biomarkers. The process is non-invasive and may be used in the treatment and prevention of a range of diseases.

The collaboration between Bruker and numares aims to take the AXINON® platform to the next level. While it was previously confined to research use, the goal is to make it available as a routine, affordable clinical tool available to all patients. One project involves the launch of a novel blood test that allows for the identification and quantification of impaired kidney function. Another test already available determines lipoprotein subclasses in serum.

This collaboration follows other fruitful partnerships that numares has formed. In 2017, the company collaborated with Oxford University in the development of diagnostic tests for multiple sclerosis. And in 2019, a collaboration with Mayo Clinic Laboratories led to the development of clinical diagnostic tests that utilized NMR technology. These tests analyzed metabolite constellations and focused on several types of disease, including kidney disease, liver cancer, and cardiovascular disease.

"While MRI is now a staple in today's world of diagnostics, the research and innovation around NMR techniques doesn't stop there."

Ultimately, there is hope that bringing advanced NMR diagnostic techniques to the frontline health care industry will allow for the swift, cost-efficient diagnosis of a broad spectrum of diseases.

***Aimee O'Driscoll**, BSc, MBA, has a decade of experience as a development chemist and is a seasoned science writer. She can be reached at aimee@aimeeodriscoll.com.*

FOR ADDITIONAL RESOURCES ON NMR SPECTROSCOPY, INCLUDING USEFUL ARTICLES AND A LIST OF MANUFACTURERS, VISIT WWW.LABMANAGER.COM/NMR

The BIG Picture

TACKLING THE TOPICS THAT MATTER MOST TO LAB MANAGERS

To see the lithium-ion battery and other Big Picture series, please go to *Lab Manager*'s website: **LabManager.com/big-picture**.

Lithium-ion batteries are in the news on a daily basis as they help transform the way we store and use power. These powerful batteries are a key component of many countries' approach to addressing climate change and our ability to transition away from using fossil fuels for transportation. Producing high-quality lithium-ion batteries is a complex process involving innovative science from several different disciplines. To make even higher-performing batteries, and to keep them safe for use, requires high-purity components. That high purity requires highly sensitive and highly specific analytical methods and instruments. In this Big Picture series, we'll explore the analytical characterization required at different stages of lithium-ion battery production—from mining and refining through battery cell production—and including recycling used batteries to recover the high-purity lithium.

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