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White paper written by Greg Weddle and Hannah Hahn

CBRE
INTRODUCTION

The R&D Laboratory of the Future

The past 50 years have been characterized by major advances in instrumentation and computer modelling, which are changing the way scientists work. Laboratory design, however, has often failed to evolve in line with these advances and the changing needs of researchers. The primary goal of the laboratory remains the same: experimentation. But the paths to discovery, and the way scientists work and interact, are being revolutionized by emergent technologies including smaller, more powerful instruments, robotics/automation, computer analysis and advanced communication systems.

The challenge now is to create laboratories that integrate and optimize these technologies while also providing scientists with the right environment and services for innovation and creativity. A study on laboratories claimed that the typical academic lab design emphasized technical and manipulative details at the expense of meaningful, conceptually driven enquiry\(^1\). This is important because academic laboratories have traditionally provided the blueprint for many early professional R&D spaces. Even today, a typical lab in the life sciences industry will devote 49% of its square footage to wet lab space and just 7% for collaboration, with almost no dedicated space for thinking and contemplation\(^2\).

This paper highlights changes taking place in the life sciences industry and envisages ways in which these changes will influence how laboratories of the future are structured, equipped, staffed, operated and maintained. CBRE’s Life Sciences team uses information obtained from internal and external sources to inform the perspectives presented herein. In particular, we draw upon a benchmarking study of laboratories completed in 2014 that gives a good indicator of the shape of modern labs and how they are used. In this study, we collected data spanning 24 labs in three global regions across four leading pharmaceutical companies. Additionally, more than 68 laboratory professionals responded to a questionnaire and contributed quantitative data on occupancy, instrumentation, spatial use and collaboration space. Qualitative data was also collected on topics pertaining to ways of working, efficiency and effectiveness and collaborative working environments.

This is a time of profound change for the life sciences sector. A “perfect storm” of forces and factors are forcing companies to reconsider how they conduct R&D, among them:

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**The death of the blockbuster drug**

The blockbuster model of drug production – those whose products generate more than $1 billion in sales – revolutionized the pharmaceutical industry in the 1980s and 1990s. The success of this model is part of the reason for the current landscape regarding laboratories. Medicines, such as the statin Lipitor®, were generating annual dollar revenues in the tens of billions. This resulted in drug companies investing in thousands of square feet of lab space. However, this model is now in decline with pharma companies struggling to replicate their previous mass success. Partly this is because in terms of drug discovery much of the “low-hanging fruit” has already been picked, especially when it comes to small molecule drugs. Pharmaceutical firms are investing twice as much in R&D as they did a decade ago but are producing just 20% of the resultant medicines\(^3\).
New drugs and new working methods
The long-term trends are towards personalized care, data-driven discovery and the digitization of lab spaces. The tracking of the human genome is increasingly allowing the creation of targeted medicines aimed at smaller patient cohorts. This means drug companies will produce larger numbers of drugs targeted at small patient subgroups. The move to personalized “smart health” will affect both drug development methods and production, which will have to be more adaptable to cope with production process changes and smaller batch sizes. Hyper-flexible spaces that can be reconfigured as needs change will become more important.

A global context
As emerging markets become more important to major companies, R&D units are relocating to countries that have a lower cost base and are closer to new markets. By 2025, it is projected that two-thirds of the world’s population will live in Asia. Per-capita health spending in these markets today remains significantly below Western levels. The ability to collaborate quickly and efficiently among global locations will be more vital than ever.

Commercial pressures and time to market
The average development time for a new drug is more than 10 years and the cost averages $2.6 billion. This paradigm creates incredible pressure for drug companies. The need to shorten the time between drug development and launch requires new ways of working, as well as a closer relationship between scientific and commercial teams. At the same time, changes in innovation and product complexity have resulted in more onerous regulatory demands.

The impact of these trends is that organizations are placing more emphasis on speed to market and maximizing the use cost for their research facilities. There is intense scrutiny on the return on investment (ROI) for all R&D projects. These pressures will continue to drive toward higher instrument utilization and closer integration of sales and marketing teams, with researchers spending less time in the lab and more in analyzing the output of the lab to discover what the data means. In this way, in silico research—e.g., performed in a computer environment through analysis and computation rather than in chemical or biological media—will increase in importance.

This report considers the range of ways that laboratories are likely to evolve over the next 25 years. It examines the range of lab types currently in use against the science activity they support and anticipates how these uses are changing based on new needs. It also considers how technology will impact laboratories and how design can provide flexibility within this changing landscape. Finally, it examines how Facilities Management (FM) partners can influence the development of modern, efficient lab environments.

Trends from the research include:
• Increased need for flexible labs that allow rapid configuration changes based on scientific needs.
• Growing importance of in silico modelling research and collaborative tools, such as video and virtual conferencing, as R&D becomes increasingly global in nature.
• Need to improve work flow and throughput for instrumentation to increase efficiency of the R&D process.
• Importance of sustainability and energy programs in order to cut costs, protect resources and improve the environment for workers.
Figure 1: Select trends impacting future lab design
The graphic below depicts a few of today’s trends that will impact the design requirements of labs of the future.

LABORATORY OF THE FUTURE

MORE COLLABORATION SPACE NEEDED

| Wet Lab Space | 49% |
| Set Aside for Technology | 19% |
| Devoted to Collaboration | 7% |

A typical lab in the life sciences industry devotes 49% of its square footage to wet lab space and just 19% for technology and 7% for collaboration, with almost no dedicated space for thinking and contemplation.

OPPORTUNITY TO RIGHT SIZE GEOFOOTPRINT

The size of research facilities around the world varies due to norms of proximity and emphasis of research. We anticipate less variance in the future as labs in the East expand research capabilities and labs in the West become more specialized and adopt flex lab arrangements. $1,026 COST PER SQUARE FOOT

180,000 SF
US

60,000 SF
CHINA

PRODUCT DEVELOPMENT DEMANDS MAXIMUM EFFICIENCY

Product development in the life sciences industry is notoriously costly and comes with a high rate of failure. This paradigm demands maximum efficiency through the development lifecycle.

Failure rate in the life sciences industry for product development.

>99.9%

Source: CBRE Life Sciences Practice

TECHNOLOGY ADVANCEMENTS CREATE OPPORTUNITIES

5.6M Worldwide shipments expected in 2019

As an example of how technology advances are impacting laboratory design and services, 3D printer shipments are forecast to more than double every year between 2016 and 2019. The FDA has already approved one drug produced through 3D printing, and it won’t be the last.
CHAPTER 1:
INTERPRETING THE TRENDS OF TODAY

It is imperative to base work on outcomes rather than places, to look at the tasks people need to perform for those outcomes, and to design the places around the tasks.
What drives people to innovate?

The ultimate goal of lab design is to foster innovation, support science and keep scientists safe, while delivering the greatest value for research investments. In the current uncertain economic climate, there is great pressure to increase R&D productivity and improve speed-to-market – especially in the life sciences industry, which has a 99.9% failure rate for product development[^1]. The environment in which scientists work can increase their efficiency and promote innovation. An important aspect of designing such an environment is identifying the optimal design for the functional need. The ideal space for free-thinking lab activities, which may require more collaboration between diffuse teams, is very different to the requirements of an open lab, which may have a greater need for elements such as instrument uptime analysis and automation. Some functional configurations of lab space are outlined below.

### An overview of laboratory configurations[^6]

#### Open Concept
Groups several lab stations of similar science use into a large common space designed to congregate researchers, instruments and support staff. It was a first step toward an Open Lab.

#### Open Lab
Typically houses specialty analytical instruments for use by multiple scientists, leveraging investment into key instrumentation. Requires convenient accessibility, high instrument uptime and easy instrument setup, teardown, cleaning and validation.

#### Flex Lab
Allows configuration changes based on scientific need without implementation of a complex facility modification project. Variable in the degree of flexibility, but normally allows basic movement of furniture, instruments and utilities.

#### Traditional Lab
Constructed for a broad range of desktop experimentation. Designs are based on repetitive workstations of utilities (water, gases, waste path), and the safety of scientists. Majority based on classroom laboratory configurations from the early to mid-20th century.

#### Collaborative Lab
Provides space for other roles in the lifecycle of discovery. In this space, disciplines such as marketing, sales and manufacturing are brought into close proximity to scientists. The goal of the collaborative laboratory is to draw ideas and improvement from everyone involved in the impact and delivery of an innovation from the lab.
Research by CBRE into lab usage in the life sciences industry gives an indication of the state of modern labs and how they are used. A survey of 24 labs in three global regions showed:

- Wet Laboratories take up a significant amount of floor space in a research facility.
- The size of research facilities varies greatly across the globe. In the U.S., the average size of a lab building is more than 180,000 square feet. This compares with just over 60,000 square feet in China.
- Lab space is expensive. The average cost per square foot is $1,026 for new lab space, 51% above best-case costs, not to mention the energy to operate it.
- Flex labs account for only 18% of the best-in-class laboratories, despite the growing need for agility and the breaking down of traditional research boundaries.
- As shown in Figure 2 below, just 19% of lab space is set aside for technology, while only 7% is designed for collaboration.

**Figure 2: Utilization of space in a R&D lab**

The chart below outlines the breakdown of R&D space in the average lab.

![Chart showing utilization of space in a R&D lab]

Source: CBRE Life Sciences Practice

However, the type of lab required depends on the work being carried out. One design does not fit all. This premise aligns with the principles of activity-based working, which is already well-recognized in continental Europe. Under this ethos, it is imperative to base work on outcomes rather than places, to look at the tasks people need to perform for those outcomes, and to design the places around the tasks. As technological change accelerates and alters the way research is performed, the physical spaces in which people work will have to be reconceptualized.
The approach in Figure 3 takes four scientific areas – analytical chemistry, microbiology, automation and device – and maps them against specific research phases or activities. This approach allows us to test and verify the type of labs that would best fit the desired activity and science. While the matrix above shows the lab designs that are typical within each science focus based on functional need, one can understand the options and value that alternative types can provide for a specific situation and desired outcome. For example, traditional lab types may be optimal for Quality Assurance testing. Collaborative, open-concept and flex labs can be appropriate in areas such as in silico and free-thinking research.

As the importance of these research functions increases over the next 25 years, so will the need for laboratories that can accommodate them. As Figure 4 shows, the importance of in silico research will increase 19% by 2029. Meanwhile, the importance of flex labs will increase 21%, while the need for traditional lab space will fall by half (see Figure 5), driven by high-tech development in modelling, AI, instruments, analysis and collaboration tools.
Meanwhile, in terms of where researchers actually spend their time while on site, there will also be major changes. CBRE Life Sciences research indicates they spend around 50% of working time in typical wet lab space or support zones. This will fall to around a third in future, with researchers spending more time in team-based environments, formal and informal meetings and wireless work zones. This will be driven partly by a new generation of scientists, used to constant connectivity and flexible working models, entering the workplace.

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**Figure 4: Changes in importance of research resources 2014-2029**

The chart below shows how the resources for lab research are expected to increase over time.

![Figure 4](chart.png)

*Source: CBRE Life Sciences Practice*

**Figure 5: Changes in lab types**

The chart below shows that the need for open and flex labs will increase over time and the need for traditional labs will decrease.

![Figure 5](chart.png)

*Source: CBRE Life Sciences Practice*
TRENDS AT WORK

The rise of the Digital Native

The move towards more digital lab spaces is a reflection of the new generation of researchers, known as “digital natives.” This new generation is accustomed to digital technology because they have grown up using it. The attitudes and expectations of digital natives are changing the workplace. They use technology to connect to their network and get information on demand, and they are comfortable analyzing large data sets. They also have a different attitude towards life, with a greater focus on maximizing personal experience. These preferences and attributes are feeding into lab design, which will include more flexible working practices. The evolution of workplace design in office space is setting expectations for lab professionals. Just like software engineers and marketers, lab professionals would like to work in an environment that reflects their values and how they work. The trend is only expected to grow as each new generation enters the workforce. Experts consider the generation that includes current eight- to nine-year-olds to be especially interesting: They were born in 2007, the year the iPhone debuted, and have never lived without smartphone technology.

Addicted to technology

Social technology is also changing communication patterns in the workplace, with many different options available ranging from instant and group messaging to software platforms such as Yammer and Slack. The advantages are many: Collaboration is instant because groups are taking part, and the information is searchable so a participant’s expertise can be tapped when they are on vacation, out of office or after they have left the organization.

Perhaps more interesting is the psychological impact on the people using this social technology to communicate. They become accustomed to collaborative and shared communication rather than one-to-one interaction. Collaborative communication in turn encourages transparency and fewer information silos. The incoming generation is therefore more inclined to collaborate than its predecessors and less inclined towards traditional hierarchies. Labs are frequently designed in order to attract scientists to a familiar environment – and this will continue. The digital lab will be tailored to fit the expectations of the next generation of researchers. Previously, due to hierarchical demands, principal investigators (PIs) were isolated from other lab employees via closed-off offices. However, that is changing. The hierarchies that used to dominate the laboratory environment will begin to be replaced with flatter structures based on speciality interest rather than a boss/employee model.
Connectivity and collaboration

Driven by a greater need for speed to market and a new generation of scientists that expect flexible working, future laboratories need far greater space set aside for collaboration, enabled by technology and design concepts. An average of only 7% of lab space currently is set aside for collaboration.13

Hot desking has been around for a long time, but increased sophistication and access to Wi-Fi has made it more prevalent. The same can be said of the rise of the “Bring Your Own Device” movement, where employees bring their own smart devices into work, fully expecting to use their personal phones, tablets and computers for professional purposes. As these trends continue, more space can be allocated for plug-and-play areas, such as cafeterias, break zones and outdoor spaces.

Modular planning principles will be used to create a collaborative, flexible lab floorplan that can be used as a rotating lab. This means each lab space must be essentially the same size to allow for changes in lab furniture, bench space and overall layout. All wet workstations must include water, gas, power and air in order to serve any scientific discipline that chooses to use that open concept or flex lab for the day.

Recent advances in building and construction have allowed traditional architectural components to further empower the overall design of the flexible lab environment. Today’s (and tomorrow’s) labs are aided by the ability to prefabricate building elements. The simplification of mechanical, electrical and plumbing systems and the use of high-tech environmental controls allow materials to be adapted to nearly any requirement, be it regulating temperature for an insect lab or dimming the lights for fluorescence microscopy research. It also is important to note that the majority of new lab space in today’s real estate environment stems from reconfiguring existing building shells rather than new greenfield facilities.
Employee engagement

An important differentiator in attracting talent and engaging employees is creating compelling lab space. It already is common in the life sciences industry to have large, campus-style facilities with carefully cultivated outdoor areas and numerous cafe settings in places of confluence between the buildings, so that employees can congregate, socialize and work. Research has suggested that employees who are given a choice over how, where and when they work have higher levels of satisfaction and innovation\(^\text{14}\). Such arrangements can include flexible office plans and adjustable desks so employees can tailor their work environment to their needs. In the future, laboratories will go even further in a bid to establish workspaces that not only foster creativity but also improve employee wellbeing.

The meaning of “health” is also changing in our society into a holistic concept of wellbeing. Being “healthy” now implies proactive maintenance as a matter of personal responsibility and dedication. Organizations have begun promoting the benefits of maintaining a healthy and mindful lifestyle as a means of increasing productivity, decreasing absenteeism and increasing the loyalty among employees. A recent study\(^\text{15}\) has confirmed that employees exhibit more loyal behavior towards employers that take ownership of health, wellness and wellbeing of their staff (75%). Additionally, 97% of the respondents believe that having a health, wellness and wellbeing strategy provides additional value to an organization in terms of increased productivity (63%), employee satisfaction (62%) and employee engagement (44%). As new science and research requirements prompt organizations to develop new labs, industry participants should continue finding ways of using design to engage their employees.
CASE STUDY

The Crick Institute

A recently developed lab leveraging new collaborative technologies and architectural plans that build towards the lab of the future is the Francis Crick Institute. It started with a plan to build a “superlab” in London’s Millennium Dome (now the O2 entertainment venue) and ended as a $1.1 billion, 93,000-square-meter institute next to St Pancras International station. By 2021, it will be home to 1,600 scientists and support staff.

One interesting organizational innovation is that researchers will not belong to departments or set locations. Their working area instead will be dependent on the items they have to use, whether these are drug-screening robots or cell sorters. They will organize themselves into interest groups rather than along traditional hierarchical lines.

The physical structure of the facility is also different from the norm and points towards what the lab of the future will look like. The layout consists of open-plan labs, and the sheer scale of the project is massive; the total floor space is the equivalent of 13 football fields, over several floors. Technology is omnipresent and navigation is informed by app rather than by map. Sensitive equipment is located in the basement shielded by concrete slabs to avoid interference from trains.

Crucially, the structure will contain spaces for interaction between different researchers. Each floor will have meeting rooms, tea and coffee stations, and above all dedicated collaboration spaces. It is believed that young people will benefit most from these collaborations. The early signs are that this will be a prototype for future lab design.
CHAPTER 2: EMPOWERING THE OPPORTUNITIES OF TOMORROW

The growing convergence of different research areas—the so-called Third Revolution—is increasingly merging life and physical sciences with engineering to produce new scientific advances.
Employee empowerment

In the future, organizations will use advances in technology, data analysis and collaboration to make lab workers more efficient. Technology-enabled work processes, such as cloud-based R&D or online experiments, will allow researchers and scientists more flexibility in when and where they work. Furthermore, scientists and researchers will be empowered to work and collaborate outside of the R&D lab and also to have productive downtime.

Employers may choose to incentivize their employees to stay as healthy as possible, and may prompt interventions if serious issues such as stress or depression are manifest. By encouraging employees to use health-monitoring devices, for example, companies could monitor health indicators, such as blood pressure and glucose levels, and suggest remedies such as taking walk or a break from current activity.

Technology that helps people manage their moods is already in development, such as intelligent glass windows that can adjust to allow optimal amounts of sunlight into an office. Employee empowerment can be pushed as far as using the concepts of gamification to educate staff and foster motivation and creativity. Employees also will have at their fingertips new types of technology whose development is the result of increasing convergence of science, technology, production and process. In this way, companies will focus less on how to engage employees and more on how to empower them using available technology in the working environment.

Convergence and the “Third Revolution”

The growing convergence of different research areas—the so-called Third Revolution—is increasingly merging life and physical sciences with engineering to produce new scientific advances. Convergence requires increased collaboration to handle the complexity of interconnecting products.

A good example of the innovative powers of convergence is the development of wearable tech products in healthcare, which incorporate medical science with data analysis and product design. Researchers at St Andrew’s University in Scotland are developing a technique that allows the insertion of micro-lasers into living cells to track them within the body, like a QR code for each cell. The power and promise of convergence is perhaps most apparent in the field of medical device production. For example, a Boston-based research company recently developed a small device that sorts and analyzes blood cells – in particular, circulating tumor cells (CTCs), which are considered the root of incurable metastatic cancers. Detection of CTCs in the bloodstream has been notoriously difficult. The device, known as a CTC-chip, has proven extremely sensitive and accurate. In one study, the chip detected CTCs with 99% accuracy. This breakthrough is the result of combining physics, engineering, biological and clinical principles to solve a daunting challenge17.

In the future it will be increasingly important to house other research areas, as well as functions such as marketing sales, in close proximity to researchers. The key is connecting ideas to actionable products and outcomes. By 2020, researchers will spend 30% more time in meetings and their offices and 20% less time in their laboratories18, although this trend will be most pronounced in free-thinking and campaign lab activities. In general, lab spaces will become more sociable and more collaborative in an attempt to drive productivity and to foster interaction between different generations of scientists.
End-to-end process improvement

Another factor that will shape the lab of the future is advancements in process design: How can processes be put in place to more effectively carry a product from concept to delivery? Like many departments within organizations, the lab has often been a silo on its own. In the future, labs will need to integrate and operate seamlessly as part of the business, performing mission-critical tasks and above all collaborating with disciplines including manufacturing and marketing.

In many ways, the life sciences industry needs to catch up with the rest of the world. A company like Apple conceives a product, pilots it in manufacturing, markets it and puts it into distribution at scale. There is no equivalent in life sciences at the moment. Yet there is a great need for increased productivity. What’s more, globalization and an aging population are creating increased demand in new markets as well as for new treatments.

One way of achieving an integrated end-to-end solution is through the creation of R&D innovation districts. This involves establishing a critical mass of knowledge in a single geographic area. It includes R&D as well as myriad support services, such as finance and commercialization. One example is North Carolina’s Research Triangle Park, which is home to 190 companies and 50,000 workers. The park’s 50-year plan includes a greater concentration of buildings and companies, as well as residential units and a light railway. An innovation district requires the interplay between economic, physical and networking assets. The individual labs may be smaller and take up far less space, but they are aligned in a tightly integrated ecosystem as noted in Figure 6. This encourages entrepreneurship and more of a shared-risk model, which increases innovation. The R&D medical hub Biopolis in Singapore is a good example. It has multiple private- and public-sector research institutes located on the same campus. The result is product output across a number of fields, including biotech, medical devices, and food and nutrition.

Figure 6: Interplay of an innovation ecosystem
Attributes of the tech- and data-enhanced lab

Smaller, faster, more powerful equipment
Scientists constantly face funding pressures. To overcome these limitations, they must use resources efficiently. One way to achieve that is through instrument miniaturization. Manufacturers have been miniaturizing scientific instruments for the better part of a decade now and the trend will continue. When an instrument is miniaturized, it’s not just the benchtop footprint that is affected: Assays and sample volumes become smaller; reagent costs are lowered; instrument sensitivity and precision are increased, and assay throughput is boosted. This saves laboratories time and money. Hence, smaller instruments make researchers more productive with less floor space. The average cost of building new office space is $1,026 per square foot, according to CBRE Life Sciences. Any reduction in this can generate huge cost savings, not including reduced operating costs.

Laboratory designers picked up on this trend a few years ago and have already implemented changes to capitalize on smaller instrument sizes. The most noticeable change in lab design is the reduction of benchtop space. Traditionally, lab benches were extremely long and bulky to accommodate larger instruments, such as spectrometers and chromatographs. Now, however, as manufacturers are perfecting smaller instruments, lab designers have found they can decrease bench length by up to 25% without causing any workflow problems in the lab.

For example, compact spectrometers have recently taken the instrument miniaturization trend to a new level. Ocean Optics’ STS-UV microspectrometer is 40 x 42 x 24 millimeters and weighs only 60 grams (two ounces). It is small enough to fit in the palm of a hand, and is powerful enough to test biological samples, water, soil and more.

In another form of instrument miniaturization, manufacturers have begun to design/arrange larger equipment vertically rather than horizontally. Whenever possible, manufacturers will integrate modules into the inside of a large instrument, such as a chromatograph. For example, Thermo Fisher Scientific’s Vanquish™ Flex ultra high-performance liquid chromatograph (UHPLC) incorporates an integrated modular design and space for solvent bottles at the top of the instrument, rather than to the side. This form of instrument design is in direct correlation with reduced lab bench space and overall miniaturization.

As equipment becomes more advanced and multifaceted, laboratory space can be used more efficiently. Johnson & Johnson recently merged three discovery facilities into a single multipurpose building, saving 110,000 square feet of space in the process. The closer proximity has also aided collaboration. As seen with the Crick Institute, scientists are not as segregated by department but are located according to the instruments and equipment they use. This results in flatter hierarchies and greater cross pollination of ideas.

Embedded technology
Perhaps the next frontier for miniaturization will be using technology to augment human experience. As mentioned, this development is part of a wider trend that sees greater convergence of different scientific disciplines such as biotech, computer science and engineering. Researchers at Harvard’s Wyss Institute for Biologically Inspired Engineering are working on engineering microchips containing living human cells to replicate the way human organs function in vivo. These “organs-on-chips,” as they are called, are composed of a clear, flexible polymer and are roughly the same size as a computer memory stick. They contain hollow microfluidic channels lined by living human cells. This allows researchers to replicate the actual mechanical functions of an organ and to observe results in real time. In essence, they allow researchers to observe the inner workings of human organs but without having to actually invade a living body.
Researchers ultimately want to create an integrated system that links all body organs-on-chips together. While the Wyss team has successfully built an integrated “chip farm,” there is still a lot of work to do in this biological engineering research area. The dream scenario is not just one “lab-on-a-chip,” but 1,000 “labs-on-chips” for 1,000 different individuals with different gene types.

**Automation**

Other laboratory equipment is moving away from batching instruments to more continuous flow instruments. Most industries are now looking for single instruments that can process multiple sample types – the more markers or analytes you can identify on one instrument, for example, the better. Again, miniaturization is the key to doing more with less, but these continuous flow instruments are also indicative of the push toward lab automation.

Automation in laboratory equipment typically involves an instrument that enables walkaway analysis or one that can run samples 24/7 even while unattended. Testing capacities, workflow, maintenance, turnaround time and return visits are just a few other characteristics that go into defining successful laboratory automation.

**“Shy technology”**

The lab of the future will be run by “shy technology” systems that are seamlessly integrated into working practices, with their complexity hidden behind the surface. Much of this technology will become so ubiquitous that it is barely noticed, especially as devices are designed to communicate and network with one another. An example would be a piece of lab equipment that signals when it needs a component change and orders the replacement without human intervention.

Important features include:
- Evolution of new analytical instrumentation and laboratory equipment
- Visualization technologies
- Built-in technologies
- Remote technologies
- Collaboration technologies

**Performance enhancements: from stimulants to implants**

As provocative as it may seem, tools in the lab of the future may include personal performance enhancements including “smart drugs” and neural implants. The desire for humans to enhance their capabilities and improve their performance is almost universal, and stimulants such as Ritalin (methylphenidate) – which was initially developed to treat children with ADHD – are already commonly used off-label by people looking to improve concentration and other cognitive abilities. Performance-enhancing operations on the brain – such as neural implants – may be the next step in human enhancement, although these are still a vision of the future rather than impending reality. What’s clear is that the relationship between artificial intelligence (AI) and scientists will also become more central, which will help shape lab design and the way technology is used.
TRENDS AT WORK

The rise of the robots

California-based Transcriptic is a robotic cloud laboratory for the life science industry. Inside the 10,000-sq.-ft. facility, laboratory equipment is linked by robotic arms, which move wellplates, pipette liquids and set incubator temperatures. The robots know what protocols to run because a researcher requests them on the company’s website. Once the experiment is complete, the system can send samples or provide digital data. This is in extreme contrast to the traditional scenario where individual labs buy their own equipment, take up their own bench space and run their own experiments. Automated instrumentation will continue to be a trend, and manufacturers expect to perfect the process even further as consumer demand for a faster, less manual workflow continues to grow.

Artificial Intelligence

How far can AI go in shaping the Lab of the Future? As machine learning evolves, it is increasingly focused on replicating the way humans learn, rather than mastering single, isolated tasks. An artificially intelligent “robot scientist” called Eve that can screen drug candidates is under development at the Universities of Aberystwyth and Cambridge. But AI that can think intuitively and creatively is the next step. DeepMind Technologies, the UK-based AI company recently bought by Google, is already working on these problems and has a goal of creating “AI scientists” although it could be decades before this technology is perfected. Most current AI is preprogrammed, but DeepMind has created software that can master video games without ever being programmed on how to play. In this way, the lab of the future could be staffed with AI systems that can conduct experiments and make conclusions after learning in the same fashion as humans. They could even perform better than their human counterparts as they will have greater accuracy and will not suffer from some of the same biases to which human researchers may be prone. They can also work round-the-clock without tiring, resulting in huge productivity gains.

From 3D printing to 3D bioprinting

Another example of automated lab equipment is three-dimensional (3D) printers. 3D printing is essentially layered manufacturing. What varies project to project is what is actually being layered and why. As the cost of both parts and materials for 3D printers has rapidly decreased in the past five years, the tool has become more prominent in laboratories everywhere.

According to Gartner’s 2015 report, worldwide shipments of 3D printers are forecast to more than double every year between 2016 and 2019, by which time they are expected to reach more than 5.6 million. The FDA has already approved one drug created through 3D printing and it won’t be the last. The technology is becoming pervasive, and not just in life sciences; 3D printers can be used successfully in almost any laboratory. They have even been used in the lab to make equipment, such as centrifuges.
As industries such as life sciences become more technologically focused, the volumes of data that are generated and analyzed will grow exponentially. Labs must be equipped to deal with this new reality. For example, the predictive modeling of biological processes is already identifying drug targets, but the data sets can be enormous. These changes will affect how laboratories are set up. Traditional wet lab space will fall in importance with a greater share of space assigned for technology, such as that described above, and computational analysis. CBRE Life Sciences estimates that only about a fifth of lab space currently is set aside for technology, but that this will increase significantly over the next 25 years.  

As researchers and scientists generate and process more data, laboratories will need to establish data center strategies that align with their throughput storage and density demands. Organizations may need to add on-site data storage space or move data centers and data center components into off-site SaaS applications or virtual data environments. These decisions will need to be made as part of a broader analysis that should occur as lab spaces evolve and their technology options change.
Collaboration tools come of age

Collaboration must be flexible and not only focused on proximity and face-to-face interaction. Future labs will have a lot more access to the interactive technology that makes this sort of collaboration possible, as well as numerous other advanced and automated systems that make running a laboratory more efficient. A number of collaboration-enabling innovations are described below.

**Telepresence**

Telepresence technologies are evolving as they migrate to cloud-based services and can be utilized effectively on portable devices. Virtual walls that can be used for conferencing and then converted for other uses are in development. Healthcare 3D modelling, which can be used for everything from training doctors to providing diagnosis, is another exciting telepresence application. CBRE research indicates that the use of video conferencing will increase by 17% by 2029.\(^{23}\)

Development of labs incorporating virtual reality (VR) also are in the future. These fully immersive virtual spaces could be used for education, as well as for conducting experiments and other business needs. In this world, the VR is so realistic that you can touch, feel and hear as if you are actually present. The uses of such technology are myriad, and could reduce the need for physical locations for many lab functions as well as speeding up the product development cycle. What’s more, experiments that are too dangerous or costly to undertake in a regular lab could be conducted in a virtual environment.

**Smartglass**

Another supporting technology is smart glass, the use of which scientists expect to increase by 14% by 2029.\(^{24}\) The future lab could provide scientists with eyeglasses that allow them to view all of the information they need at a glance. Simply putting on the glasses activates them and they could then be controlled by voice or gesture. And at the same time as they are working, scientists could be in video communication with colleagues in other locations discussing protocols and results.

**Crowdsourcing**

As products become more sophisticated, new working methods are under development to overcome market pressures, including lengthy development cycles, high costs of production and onerous regulatory demands. Companies are utilizing new tools and innovative methods to reduce time to market, which is a critical need. For example, recent developments in connectivity – such as social media and crowdsourcing platforms – are being used to broaden the pool of clinical trial participants, while online tools are employed to screen candidates efficiently. Real-time monitoring also can be used during clinical trials to quickly flag issues and prevent unnecessary delays. Pfizer has already conducted a drug trial whereby people participated from their homes using computers and smartphones.
CHAPTER 3: SUPPORTING SCIENTIFIC ADVANCEMENT WITH FM SERVICES

As the physical location of the lab and all of its equipment becomes more fluid, a team that keeps track of utilization, operation and maintenance of equipment will play a key role.
The role of Facilities Management (FM) partners will increase, with scientists claiming that use of the lab concierge will increase by 26% by 2029. Put simply, as the physical location of the lab and all of its equipment becomes more fluid—even within a vast structure like the Crick Institute facilities—a team that keeps track of utilization, operation and maintenance of equipment will play an important role.

Providing lab concierge services

Within the new networked reality for labs, third-party vendors that can manage and integrate this space will become more important. By taking care of technical considerations, these vendors will allow scientists to focus on their core work of discovery and innovation. This could be as simple as setup: making sure the gloves and the media are in the right places. However, this could also include taking a holistic view of all operations in a lab: How can science be more productive and how can technological and innovative ideas be brought to the space?

FM service providers focused on the life sciences market are naturally suited for this role, which can include: optimizing lab construct, instrumentation and associated technologies; bringing efficiencies to the throughput of the science performed in the lab; and managing the material flow and utilities required to support that space. In this way, FM service providers are well-positioned to enhance the scientific experience even as the science use or functional demands of the lab evolve.

Improving space configuration and flow

At the moment there are several impediments to a streamlined lab process. These include sub-optimized flow of people, materials and data. The task of the lab concierge, armed with the right technology and process improvement tools, is to optimize these processes. Analytic tools such as LavSAVi, which analyzes a lab’s general uptime, could aid the lab concierge. CBRE estimates that 75% of equipment failure is tied to improper use. As equipment becomes more complex, it must be accompanied by detailed education programs, while reporting tools can help analyze and manage usage to ensure greater uptime. Intelligent dashboards can offer a real-time view of what is happening and where, who is interfacing with what and how it could all be better deployed.

Optimal efficiency with instrumentation allows an institution to increase its productivity without extra investment. Tools are now available, for example, in the nuclear and aerospace industries that use probability quantification to model systems and calculate failure probabilities. Such a system helps create a virtuous circle where, armed with relevant data, FM partners can make recommendations about design versus success probabilities of infrastructure systems and instrument function and configuration in the future.

One key will be standardization. The only way to handle the constant deluge of data is the establishment of uniform protocols. The standardization of data will allow organizations to effectively integrate a large amount of information from multiple sources, be it a satellite office, an employee’s home office or even another company. Standardization will enable more effective R&D collaboration through simpler and better information exchange in the overall life science laboratory. Still, the amount of data currently being generated outweighs our technical capacity to evaluate it. The pure volume involved requires the development of more robust tools if researchers ever hope to accurately interpret and utilize the valuable information.
Enabling seamless integration of services

Numerous technological solutions offered by FM providers are available now, or are in development, to make labs run more efficiently. These include:

- Instrument maintenance management systems
- Adverse event management and tracking tools
- Learning management services
- Stockroom/inventory management software with reporting and analysis capabilities
- Asset utilization analytics

Developing facility strategies for the future

This paper discusses many advances in technology, process, design, workplace behavior, analytics and manufacturing that will affect the way laboratories of the future are structured, equipped, staffed, operated and maintained. But it is important to note that laboratories, just like other workspaces, have unique functions and features. As discussed in chapter one, the requirements of analytical chemistry, micro biology, automation and device research require functional lab activities that are best pursued in discreet lab types. These lab types may include collaborative, open concept, open access, traditional and flex spaces. Because the science use and functional demands of each lab type are different, not all future innovations will apply to laboratory space in the same way.

How then should organizations plan for these coming innovations? Since not all science is equal, the first step would be engaging in a self-assessment of how laboratory space is used today and of the business priorities over the next several years. At a minimum, organizations should be asking the following questions:

- Does my organization have many large molecule products in its pipeline? Is our science focus changing?
- Is my organization well-funded?
- Is my organization able to attract the scientists it requires in timely fashion?
- How willing is my organization to adopt new processes?

The answers to these questions will shape the strategy your organization should take in preparing for the many laboratory advances that will be available in the future. For instance, if your organization has a robust pipeline of large molecule products, is well funded, is able to attract the scientists it requires, and is willing to adopt and employ new processes, it may have the resources to pursue some of the innovative elements discussed in this paper. At the same time, necessity is the mother of invention, and organizations that must overcome limitations in funding or talent may be quicker to adopt processes and technologies, however unevenly, to make existing resources more efficient.

Business strategy, therefore, must drive laboratory strategy. This alignment can be difficult to achieve independently and can be significantly enhanced by partnering with service and technology providers whose distance from the organization can be a decisive attribute in recommending impartial guidance on a range of services. This can include assessing primary business drivers and providing best practices and benchmarks from organizations across the life sciences industry.
CONCLUSION

The lab of the future will be very different from that of today, reflecting both the challenges that R&D-focused industries are facing as well as the technological changes that will happen over the next 25 years. The main purpose of the laboratory as a vehicle for experimentation and innovation will remain, but how it will be achieved will differ.

Imagine a scenario where the R&D facilities of a major life sciences company are located in an integrated bio-cluster. These facilities could have a relatively small footprint—fewer than 60,000 sq. ft. Surrounding them are other small independent labs working in different research areas in related fields, as well as companies specializing in the marketing and commercialization of technological and scientific breakthroughs. The workers may actually live on the campus, which would have leisure facilities and housing units, as well as schools and other facilities.

As our scientific researcher enters the laboratory in the morning, she would be greeted by a dedicated lab concierge who provides updates on the outcomes of experiments and analyses that were undertaken overnight by automated instruments ubiquitously connected. The concierge gives our researcher promising findings from the AI modelling analysis as well as feedback on instrumentation uptime and productivity, thus helping her prepare the day’s lab work. As our researcher walks to her office, she passes inviting break-out spaces and cafes where colleagues chat and discuss work or take telepresence calls with scientists far afield.

As the day starts, she meets with the rest of her team, which includes scientists from numerous fields and geographies, but who are working together on the same project—say a new medical device. Smart-glass technology allows everyone to bring up the latest project information, updated from the previous night’s results and analyzed in real time, while any remote contributors also join in the discussion. A virtual reality model allows the team to walk inside an enlarged view of the cell their innovation strives to cure. After discussing the parameters of the project, the team is informed by the AI-enabled network that an instrument needs attention before they can continue with the day’s work. After checking the details, the team gives the go-ahead and the AI network instructs a 3D printer in the network to create a replacement and then installs and validates operation.

As the day progresses, the scientists work in their separate areas. The industrial engineers work on product design, while the biochemists and data scientists evaluate potential targets for their device and discuss early stage trial data, which has been conducted on genomically accurate virtual trial patients. At the end of the working day, the data is synched with similar virtual trials being conducted across the world. When she leaves the lab, the AI-enabled network continues working throughout the night, pushing the project forward while the team on this side of the world sleeps, and providing new data sets and potential breakthroughs for our researcher as she arrives the next morning.

At the moment such a scenario sounds far-fetched, but these are some of the ways that laboratories in the future could differ from today. The next 25 years will see one of the most significant revolutions in the way science is conducted. How labs are designed, how they operate and the way scientists interact with these new environments will be at the heart of the change.
REFERENCES

2. Global Pharma Group, R&D laboratory benchmarking study 2 – March 2014
6. Definitions created by Gregory Weddle, Vice President Specialty & Regulated Solutions, CBRE
7. Global Pharma Group, R&D laboratory benchmarking study 2 – March 2014
8. Ibid.
9. Ibid.
10. Ibid.
13. Global Pharma Group, R&D laboratory benchmarking study 2 – March 2014
22. Global Pharma Group, R&D laboratory benchmarking study 2 – March 2014
23. Ibid.
24. Ibid.
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