Future of Labs

ARUP

This report is a product of collaboration between Arup Foresight, Research and Innovation and Arup Science and Industry teams across the world. We would like to thank all contributors for their input and advice.

Foresight is Arup's internal think-tank and consultancy which focuses on the future of the built environment and society at large. We help organisations understand trends, explore new ideas, and radically rethink the future of their businesses. We developed the concept of 'foresight by design', which uses innovative design tools and techniques in order to bring new ideas to life, and to engage all stakeholders in meaningful conversations about change.

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Foreword

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The pandemic has thrown the world's spotlight onto scientific research. Rarely have scientists had such high public profiles – be they infectious disease specialists, vaccine researchers or public health experts. Yet the most significant impacts on scientific research facilities and the pharmaceutical industry may yet be to come.

Firstly, the attention of much of the world's research community is focused on the race to find effective vaccines and treatments for COVID-19. Already one of the fastest growing sectors of the global economy the pandemic will increase demand for pharmaceutical and biomedical research. A key challenge will be ensuring treatments are available at scale everywhere and for everyone.

But research labs and facilities are not immune to the impacts of COVID-19. So, secondly, the industry will have to implement changes in operational protocols as we have seen in other sectors. Given the spotlight that COVID-19 has shone on critical infrastructure the need to ensure safe and resilient working environments in research facilities is even more important.

Thirdly, there is an opportunity for non-lab typologies to learn from the biosafety design requirements employed in laboratories. From increasing outdoor air ventilation rates to optimising air flow patterns, 24/7 system operation, and adding UV irradiation into occupied spaces, there is the potential for cross-fertilisation and cross-innovation for other typologies.

It is too early to say whether "urban lab campus", like the Crick Institute in London, will become a thing of the past or a model for the future. Whilst we must consider density and fluctuation of people, scientific research needs to be more visible and transparent in times of uncertainty.

The research carried out in laboratories across the world is crucial for humanity's common future. Collaboration, already a cornerstone of the global research network, has never been more important and it has been heartening to see the science community coming together to support critical research.

Left: Interdisciplinary Graduate School "The Hive" at Nanyang Technological University in Singapore

Executive summary

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Science and research are key to addressing humanity's biggest challenges. They have been seminal in creating today's world and their role in the future development of mankind will most likely be even greater. Creating excellent spaces and environments for scientific research and researchers to thrive will, as a result, become even more important.

As the challenges facing science and the ways of tackling them become more complex and interconnected, researchers are increasingly working across disciplines, domains and borders. Technologies such as artificial intelligence, robotics and automation, cloud computing and web-based platforms enable novel forms of research.

These technologies are not only impacting how scientists work, but also the spaces where science happens, both inside and outside of laboratories.

In some ways, the automation and digitalisation of science means that some researchers are spending less time in traditional lab environments and more time working in desk-based and collaborative spaces. Open source tools are enabling better access to scientific knowledge, tools and data and driving increased citizen engagement with the scientific process. New kinds of research facilities such as co-working spaces, incubator hubs and DIY labs are providing spaces for research outside the lab entirely. This trend is disrupting the dominance of institutional labs as the only legitimate venue where science can occur, shifting the geography of innovation to oftentimes more urban, decentralised, informal and shared spaces.

This report examines key trends that will impact the design, operation and experience of research facilities. Key findings identified in the report are illustrated on the next page. Findings are informed by conversations with experts across industry and academia gathered through interviews and a workshop held in London in November 2017.

Throughout the report, insights are grouped into three themes across scales: people and collaboration; spaces and operation; and infrastructure and place. These themes are used as a lens through which the future requirements of scientific research spaces, and the human experience within them, are explored.

Key takeaways

Science and place

Historically the focus of research facilities has been on the science, and the ability of a building to provide required functionality. While this remains important, there will be a greater emphasis on user needs in terms of place and location, and user experience and wellbeing.

Adaptable spaces

Specialisation and diversification in science keeps growing. Alongside demand for highly-specialised spaces, the design of research facilities will become more generic. These highly-adaptable spaces will focus on technology and tools rather than bespoke designs for a particular branch of science.

Alternative places

Driven by urbanisation and increasing connectivity, the lab could be a cluster of likeminded organisations and spaces rather than a single coherent building. Emerging cloud-based labs, living labs, and DIY and co-working spaces will provide researchers access to equipment and a scientific community outside the institutional framework.

Digitalisation

Digital technologies are fundamentally changing how science is carried out, with powerful new tools to collect, analyse and share data. As robots take on repetitive or dangerous tasks – without human intervention – experiments can be monitored remotely, further challenging the concept of a 'traditional' lab building.

Networked spaces

Digital connectivity is amplifying the global and networked nature of scientific research. While physical labs and specialised equipment will remain necessary, there will be increased options for researchers to work outside of institutions altogether, operating in real-time from physically remote locations.

Drivers shaping the future of scientific research

A range of globally relevant long-term changes, as well as sector-specific drivers are transforming the scientific research ecosystem. They are reshaping the context in which scientific research and scientists will be operating in the future, as well as shaping the agenda for scientific research, the scientific research itself, and its methods and execution.

Future agenda for scientific research

The agenda for scientific research is, to a large extent, underpinned by a range of global megatrends. These range from demographic changes such as population growth, urbanisation, an ageing society and increasing incidence of chronic diseases to climate change, natural disasters, accelerating resource depletion and environmental damage, amongst others.

The future direction of science is largely being driven by the urgent need to respond to these challenges while the shape of scientific research is being reformed by wider cultural and technological changes. The complexity associated with responding to these challenges will require science to form new partnerships across geographies, political, organisational and disciplinary boundaries.[1]

Shifting geography of science

Along with these global trends and associated emerging priorities, the geography of scientific research is changing. While advanced industrial economies have traditionally dominated the global map of science, new powerhouses such as China and India have emerged as important centres of research and innovation. The spatial reorganisation of research across the globe is enabled by advances in technology and communications and the liberalisation of capital flows and movement of people.

As a consequence, the scientific ecosystem is moving away from a pyramidal structure dominated by the US, UK, Germany, Russia and Japan, towards a network model with multiple smaller, linked centres of excellence. Often these new centres will address critical niches in line with national or geographical priorities, informed by local factors, such as socio-economic, geopolitical or environmental issues.[2]

More privately funded research

The organisational structures and funding models that have underpinned scientific inquiry over the last century are fundamentally changing. Privately funded research institutions are increasingly common. Public-private research partnerships between universities and private companies such as pharmaceuticals are on the rise as universities look for alternative sources of funding. These partnerships impact the type of research projects that receive funding and how research discoveries are applied, sometimes shifting the research landscape towards an increase in applied research.[3] At a smaller but not insignificant scale, the academic publishing model is also being disrupted by open publishing platforms that provide cheaper and faster ways to publish and access research findings.

Digitalisation and automation drive analytical research

Digital and technological advances are having a dramatic impact on the way research is conducted. Robotics, automation and artificial intelligence provide scientists with new powers of inquiry and analysis that go beyond what would be humanly possible. Automation in the lab enables researchers to undertake sophisticated, high-volume experiments with exact precision over long periods of time. In some cases, this will lead to robots replacing humans in the lab for routine and highly technical tasks. Automation combined with artificial intelligence and machine learning enables researchers to undertake advanced analysis of data to gather novel insights. This is already utilised in genetic analysis to interpret genetic material and develop new therapies. In addition, cloud-based technologies and research platforms are enabling scientists to customise and control all of these technologies in addition to sharing and accessing data with remote collaborators.

Increasing competition and shorter time to market

With the digitalisation of science and new ways of working, the time it takes to move research from early stage inquiry to publication or market-ready development is rapidly decreasing. With universities playing a larger role in economic development, and private enterprise investing heavily in R&D, the pressure to innovate and commercialise research is rising. Competition between researchers and research institutions to capitalise on the ‘next big thing’ in science is driving a new ecosystem of business accelerators and startups, further blurring the boundaries between business and research.

For future scientific research facilities, this means rethinking how and where research is conducted and how buildings can enable or hinder the innovation process. An understanding of how space impacts and informs innovation activities will be needed in order to design the lab of the future. The kinds of spaces required for this new type of work will look and function very differently to the spaces we find in laboratories today.

Scientific research over time

- 1543 Copernican heliocentrism
- First scientists able to make a living of scientific research
- 1687 Publication of Naturalis Principia Mathematica (mathematical principle of nature philosophy)
- Development of first mechanical computers
- 1763 N. Jacquin established first teaching lab in former Hungary
- 1776 Declaration of independence — philosophic thoughts achieve importance in politics and economics
- The term scientist replaces more general “natural philosopher” and development of specialised training courses
- 1858 publication of Darwin’s theory of evolution
- 1975 Ed Roberts creates the first computer for private usage
- 1990 start of the Human Genome Project in the US

	pre-science	modern **physics**	modern **chemistry**	modern **biology**	**advanced technologies**
	individual interest in “how the world works” experience based	~17th century attempt to explain the world based on physics	~18th century practical experimentation to prove theoretical background	~19th century living organisms as objects of science	~21st century increase in applied and cross-disciplinary research
Focus	curiosity practicality chance	astronomy molecules atoms mechanism	alchemy study of nature transformation of substances (chemical substances and reactions)	medicine evolution zoology botanics genetics	engineering technology agriculture medicine and biology humanity
Methods	empiricism observation	numerical methods mathematics observation	practical experiments chance discovery	observation measuring comparing	analysis quantitative and qualitative methods
Mindset	science originated in philosophic/religious context religion and science belong together personal motivation/curiosity	mechanical-linear view inductive methods separation of religion and science	linear view inductive methods	linear view inductive methods	technological view impacts on society
Institutions	churches and courts very few scientific research centres	universities few/selected research associations focussed on specific fields of research/topics	universities few/selected research associations academic and industrial context	universities beginning of research endeavours in private companies	universities public and private research institutions industry/private companies (research division)
Funding	public funding (state) church royalty (noble courts)	public funding (state) private donors church royalty	public funding private donors church royalty	public funding private donors church royalty	public funding industry (private sector) non-profit/philantrophic organisations
Spaces	observation of/in nature (usually no dedicated rooms/facilities) private houses churches/cloisters	research facilities/universities settle close to trading intersections private houses churches	private houses labs as part of public research facilities establishment of first so-called laboratories	labs as part of public research facilities prevalence of traditional laboratories (designed for repetitive desk experimentation) mono-functionality	new types of labs (open and flexible) demise of mono-functionality science parks (incl. partnering of public and private sector research) smaller labs in urban context

This timeline illustrates developments in scientific research, including research focus, methods and some key milestones. It covers where we are coming from, whereas the remainder of this report considers where we are heading to.

The scientific research ecosystem goes far beyond the physical spaces of laboratories. Among many things, it encompasses the people making research possible, the places where scientific discoveries happen, and the infrastructure required to sustain innovation. Only by recognising the extents of this ecosystem can we begin to understand the complex interactions between the people, the spaces and the environment, and how the spaces we create can respond meaningfully to these varied requirements and desires.

The following sections present three key themes influencing the scientific research ecosystem: people and collaboration, spaces and operation, and infrastructure and place. These themes are used as a lens through which we can focus on the future requirements of scientific research spaces and the human experience within them.

People and collaboration

From a practitioner's perspective, this section explores the changing requirements, different ways of working, and future skillsets that will be needed by people in research environments. Key drivers are the growing interdisciplinary nature of research and the increasing public involvement in science.

Increasing interdisciplinarity

Our rapidly increasing means create ever increasing needs, and modern science exemplifies this trend. The problems that today's scientists face are increasingly complex, requiring researchers to work across multiple disciplines to deliver innovative breakthroughs.[4]

The scientific understanding of a multifaceted global issue such as climate change, for example, requires an integrated approach that combines insights from diverse disciplines and fields, such as earth sciences, physics and chemistry, to more contemporary branches like behavioural psychology.

Enabling such interdisciplinary research requires certain infrastructural baselines, particularly around connectivity and mobility, both physical and non-physical.

Multi-institutional and multi-national collaborative projects need facilities and infrastructure that are as connected as the institutions are diverse. For example, wireless communication systems, high capacity data storage and data processing, and access to transportation systems at the local, regional and global levels to enable the movement of people, goods and ideas.[5]

At the same time, a new generation of researchers is emerging that are working and thinking across disciplines. Academic programmes will need to be rethought to rapidly increase student exposure to cross-disciplinary research and thinking, and new degrees that transcend these boundaries may be required.

Beyond a retooling of academic and institutional research structures, there are also implications for the physical and technical design of labs. Researchers working across disciplines need lab facilities that are flexible and able to accommodate diverse forms of research with vastly differing technical requirements.

At the Skoltech Institute for Science and Technology in Moscow, for example, all lab spaces have been designed to accommodate any mixture of its five key science clusters — nuclear, energy, biochemistry, space and IT — with the focus on flexibility and fostering cross collaboration.

Changing nature of work

The nature of scientific work and the ways researchers collaborate with colleagues is changing rapidly. Major technological advances in automation, artificial intelligence and data processing are reducing the number of hours scientists spend in the lab physically working on experiments, freeing them up to focus on analysis, synthesis and ideation.

Increasing automation of lab processes will result in scientists spending a greater portion of their time in office-like environments. The BioData Innovation Centre at the Wellcome Campus in Cambridgeshire, UK, for example was designed to accommodate biodata startups and growing companies, and includes more office-like environments, break-out areas and meeting spaces to support new ways of working and foster collaboration.

© Robert Canfield

Case study

Clark Center, Stanford University

Designed by Foster + Partners, Stanford University's James H. Clark Center is home to interdisciplinary research that brings together physicians, biologists, chemists, engineers, physicists and information scientists. The building accommodates a wide range of activities and was designed with flexibility in mind, supporting collaboration between disciplines by enabling spontaneous social interaction and conversation. Designing for flexibility includes corridors that are located on external balconies allowing floor plates to be subdivided as needed. All labs are designed as open rooms facing onto the inner courtyard and can accommodate wet lab and office work in parallel. Lab tables and benches are mounted on rollers so that the furniture can be quickly changed or moved around for different research teams.[20]

Collaboration is a highly important driver for scientific research: this map illustrates the collaboration networks between researchers in different cities across the globe. It shows that the location of scientific institutions follows population density and highlights links between countries and their former colonies.[6]

Increasing collaboration between different teams and disciplines will require spaces that are designed with consideration for different people flow patterns and easier movement between various lab equipment stations, rooms and floors of a building. The Jackson Genomic Medicine Lab, for example, uses glass to visually connect wet and dry labs with write-up areas and other support spaces. Open plan layouts, clear sightlines and circulation between spaces encourages researchers to work together.

A better understanding and increasing consideration on how the workplace environment influences productivity and wellbeing also contributes to the design of workplaces. Productivity is increased in workplaces that provide access to natural daylight and are designed around activities, providing distinct environments for different modes of work.[7,8]

Shifting demography is also having an impact on working styles and trends, as a new and more diverse generation of scientists enter the workforce with different skills, attitudes and expectations. This new generation often prefers work environments that are more collaborative and team-based, decision-making systems that are more transparent and horizontal, and flexible working arrangements that balance personal and professional goals.[9]

Forward looking research organisations embrace these demographic shifts and adapt their workplace environments and policies accordingly. In addition to more open plan designs and flexible work options, there is a trend towards research facilities that include modern amenities for staff such as gyms, protected bicycle storage, lockers and showers, cafes and concierge services. These features are transforming the lab beyond a utilitarian research facility into a dynamic social space that can attract, motivate, and retain talent.

Case study

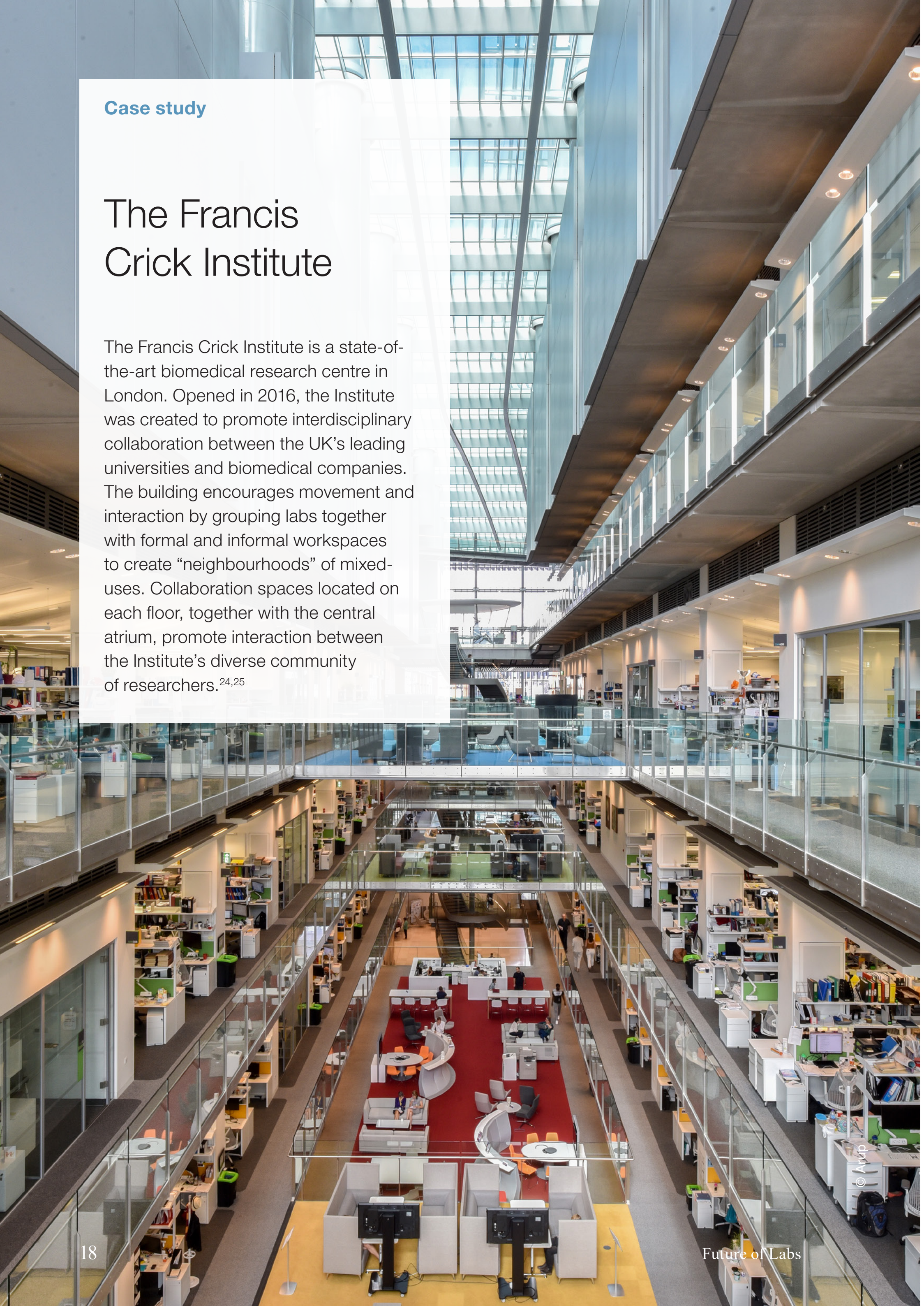
McMaster University Science Lab

The Integrated Science Lab at McMaster University in Canada is designed to support student learning in the Integrated Sciences undergraduate programme. Students take courses across a number of different fields requiring a laboratory that can be adapted to accommodate learning in physics, biology, chemistry, environmental and behavioural sciences within the same space. Flexibility is achieved through an open plan design with lab benches that do not have overhead shelves or vents and where utilities such as gas, electricity and water come up through the floor allowing equipment to be moved in and out as needed.[21,22]

Case study

German Scholars Organisation

The German Scholars Organisation (GSO) was established in 2003 to foster contacts between German academics working abroad and the scientific and research industry in Germany. Among OECD countries, Germany has one of the highest levels of emigration of highly skilled talent. In 2015 more than 3.4 million Germans lived abroad with more than 1.2 million of those possessing a university degree. In 2006, the GSO received funding from the Alfried Krupp von Bohlen und Halbach Foundation to recruit exceptionally talented German's living abroad for appointments at German universities.[23]



Case study

The Francis Crick Institute

The Francis Crick Institute is a state-of-the-art biomedical research centre in London. Opened in 2016, the Institute was created to promote interdisciplinary collaboration between the UK's leading universities and biomedical companies. The building encourages movement and interaction by grouping labs together with formal and informal workspaces to create "neighbourhoods" of mixed-uses. Collaboration spaces located on each floor, together with the central atrium, promote interaction between the Institute's diverse community of researchers.[24,25]

Case study

Experiment.com

Experiment.com is a crowdfunding platform for science. Launched in 2012 by former researchers at the University of Washington, Experiment connects researchers seeking funding for scientific projects with members of the public willing to back research with a cash donation. Like other mainstream crowdfunding platforms such as Kickstarter, Experiment works on a funding model where pledged funds are only collected if the campaign reaches its funding target. Once a project has been funded, researchers can share the progress, process methods and outcomes of their research projects with supporters.[26]

New skills and global competition for talent

The fourth industrial revolution is underway and is blurring the lines between the physical, digital and biological realms. Emergent fields including artificial intelligence, machine learning, robotics and nanotechnology are moving closer to biological and life sciences to create hybrid disciplines.[10] These new areas are creating demand for scientists who possess specialised digital skills in areas such as data science, and the ability to collaborate within interdisciplinary teams.

This has implications for the way scientists are trained. Universities need to support the development of specialist technical skills and research professionals need access to continuous learning opportunities to keep their skills up-to-date or broaden their knowledge.[11]

Increasingly, MOOCs (massive open online courses) are filling this need. Universities and companies are partnering with online platforms including Coursera, EdX and FutureLearn to offer short-courses and advanced training in emerging fields. As these platforms grow in popularity, employers are beginning to recognise certifications from MOOCs as valuable and trust them in their hiring decisions.[12]

Despite an overall global increase in investment in R&D, many OECD countries report a shortage of people with the advanced skills needed to support their science and innovation industries. While advanced economies such as the US, the UK and Germany contribute to an emigration of skilled individuals into the global market, increasingly non-OECD countries such as China and India are becoming the main sources of skilled migrants.[13,14]

With the number of highly skilled PhD graduates on the rise globally, positions in universities and the private sector are not keeping pace. In response, some researchers are seeking opportunities in the 'gig economy' as self-employed freelancers.[15] Online platforms like Kolabtree and Upworthy allow scientists to advertise their services directly to clients for a set fee. Freelance scientists find ways to overcome the limitations of

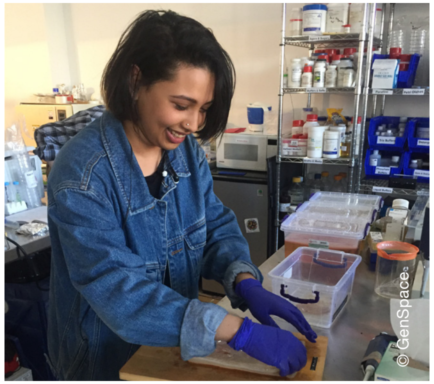
Case study

Wyss Institute, Harvard University

The Wyss Institute for Biologically Inspired Engineering develops ground-breaking research at the intersection of life sciences and emerging technologies. The Institute's scientists, engineers and clinicians work with industrial designers and experts in business development, intellectual property and entrepreneurship to develop new technologies ranging from devices and materials to high-value therapeutics and diagnostics. The facility's adaptable environment simultaneously supports chemistry and biological, mechanical and nanotech research for various pursuits, including robotics, bio-mimicry and anticipatory medical device development.[27]

Case study

GenSpace DIY Community Lab



Founded in 2009, GenSpace is a community-run DIY lab that provides access to biotechnology equipment for citizen scientists and entrepreneurs. GenSpace's mandate is to promote science literacy through educational workshops and cultural events. Past workshops have allowed participants to experiment with gene editing and to learn coding using DNA. GenSpace provides a platform for entrepreneurs, artists and designers to research and create profitable businesses, personal projects and thought-provoking bioart and design projects.[28]

Case study

Pandemic Citizen Science Project

Pandemic was a citizen-science experiment by the London School of Hygiene and Tropical Medicine at University College London (UCL) and the BBC to help researchers develop accurate models for the spread of infectious diseases in human populations.

A mobile app tracked the location of participants and logged instances when they had come into contact with others who also had the app installed. The experiment modelled a typical outbreak scenario where a "patient zero" is introduced into a population and unknowingly infects others through interactions. Coming into contact with someone with an "infected" resulted in the system logging a "transmission" of the virus. The data captured was used to develop more accurate models of viral transmission in order to improve responses to future outbreaks.

Nearly 30,000 volunteers have signed up to participate since the app was launched. Prior to this, the largest UK study of pandemic models only had about 5,000 participants and movement data was self-reported making it subject to error.[29]

working outside traditional institutions by embracing open publishing platforms like PLOS One, accessing equipment through community lab spaces, and finding professional networks through social media.

Open science

Open science is a movement that seeks to make all aspects of science, from research and discovery to publishing and education, more open and accessible for everyone. Open science is enabled by digital, web-based and mobile tools and services that help scientists conduct experiments, share research, as well as enable non-scientific audiences to access scientific data.

Online learning platforms make scientific knowledge accessible for broad audiences. Many institutions are adopting open data policies that make scientific datasets public and freely available.[16] Crowdfunding platforms are also being leveraged to engage the public as patrons of scientific research. By embracing open science, traditional research institutions can build greater public understanding and appreciation for science and support innovation at large.

The power of the crowd can be leveraged for more than just funding. Open source tools empower people to participate directly in the scientific process.[17]

“ Knowledge needs to remain something that we seek and we’re excited about — it shouldn’t always have a purpose ... There should be some level of enjoyment in just understanding the world.”

—Dr Sarah Caddick, founder and CEO THALAMIC (2017)

Enabled by mobile devices and open source tools such as Arduino, so-called ‘citizen scientists’ can become involved in the collection and analysis of data informing significant scientific research. Harnessing the crowd and citizen science helps researchers to vastly increase sample sizes and the reach of their data collection efforts.

The Apple Heart Study, for example, is a collaborative research project with Stanford University and draws on the participation of Apple Watch users to identify and study irregular heart rhythms. The purpose of the project is to improve the technology used to detect and analyse irregular heart rhythms.[18]

As the public becomes more informed and engaged with science, DIY and community-based labs are being created for citizen scientists and researchers alike.[19] DIY labs can be seen as part of the wider ‘maker space’ movement, which provide access to space and equipment for DIY makers from woodworking to 3D printing and electronics. Many DIY labs have the same community-focused ethos as maker spaces and offer workshops on a range of scientific topics in hands-on and creative ways.

People and collaboration

Key takeaways

Space for collaboration

Facilitate collaboration between disciplines and sectors with buildings that promote social interactions in common areas and laboratory facilities that accommodate multidisciplinary research.

Activity-based lab design

Organise lab spaces around different modes of working such as bench-based experiments, focused independent desk work, informal stand-up meetings and group work — and create flows between these areas.

Employee wellbeing

Attract and retain talent by designing lab environments that promote healthy lifestyles, cognitive and emotional wellbeing, and connections to nature.

DIY and open research

Promote citizen engagement with science and support entrepreneurial researchers with DIY labs and open science initiatives that democratise access to scientific tools and knowledge.

Digital skills and infrastructure

The next generation of scientists will require an investment in digital infrastructure and training for researchers with specialised digital skills.

Spaces and operation

This section looks at the future technical and operational requirements for research buildings and spaces. It explores the way lab spaces will operate in the future, and considers what changes could be needed today to support the scientific work of tomorrow. It highlights the growing importance of flexible and adaptable spaces, activity-centric and collaborative environments, new technologies and instruments, as well as building and environmental performance.

"More communication in the context of laboratory work is the key to innovation. Digital tools and devices that assist with the exchange of knowledge combined with large, light-filled and open spaces can create a positive working atmosphere."

—Christian Hunzinger, Biotech CMC Program Lead, Merck (2017)

Flexible and adaptable spaces

The trend in laboratory design and construction over the last decade has been towards buildings that are built with flexibility in mind. While it is impossible to anticipate what new technologies and forms of research will exist in the future, labs can be designed from the ground up to accommodate adaptive changes.

Flexible and adaptable lab design includes elements such as mobile benching, a structural design that enables easy access for servicing and a grid that is compatible with a multitude of space layouts to easily shift between lab, equipment and office space. It also includes the provision of a plug and play service infrastructure, consisting of a grid of services with connection points at regular intervals to allow the space to be reconfigured with ease.

As scientific work becomes more collaborative, interdisciplinary, and technologically mediated, labs will also need to accommodate new ways of working. Tactics include open plan labs with circulation and sightlines between different areas of the building; and labs with a mix of different working environments including informal collaborative meeting spaces, semi-private working stations, and unplugged zones for quiet and focused work.

Furthermore, building services need to be designed to accommodate future changes in scientific requirements. Services such as HVAC, water, gas and waste management need to be strategically positioned in labs so as not to lock-in a particular configuration. IT systems need to provide robust infrastructure for growing data storage, processing and virtual collaboration.

Intelligent labs

Newly emerging intelligent or 'smart' labs contain connected machines, equipment, sensors and devices, allowing researchers to monitor, adjust and analyse experiments remotely. For example, new instruments are coming on the market that can automate certain procedures, allowing researchers to more efficiently process experiments that require complex, multiple or repetitive steps. Machine learning will enable facilities to 'learn' from previous actions, adapting or preparing spaces accordingly, based on real-time feedback and monitoring. These technologies are dramatically changing the way scientists work in the lab and how labs are designed.[30]

Intelligent lab equipment can also help scientists collect more fine grained and accurate data about their experiments and send results to a shared database or 'laboratory information management system' (LIMS). Beyond collecting and sharing data, advanced LIMS software can be used to manage the entire workflow of labs, to execute experimental procedures, to monitor instruments and generate reports.

Case study

Core Informatics: LIMS

Core Informatics' Laboratory Information Management System (LIMS) helps researchers manage lab workflows, track and execute requests, monitor experiments, collect and share data. Core Informatics' LIMS platform can be connected with intelligent lab equipment to help researchers execute experiments and collect data on demand. The user-friendly interface can be used on a tablet or computer and supports a marketplace of extensions with custom applications for a number of common laboratory procedures. Cloud storage via Amazon cloud services allows researchers to access the service and data at all times.[46]

Case study

Transcriptic Cloud-based Lab

Transcriptic is a biotechnology lab that is accessed via the cloud. It allows researchers to remotely design and execute biological experiments via a custom API and web interface. Its 'Science as a Service' model allows researchers to run experiments and access support on a subscription fee basis. The platform is popular with startups that cannot afford to invest in their own equipment and university researchers looking to outsource simple experimental procedures with a quick turnaround. Researchers can run many projects in parallel, remotely monitor progress and view quality control data via Transcriptic's online interface.[47]

© AstraZeneca

Case study

NiCoLA-B

NiCoLA-B is a robot designed to work alongside scientists at the UK Lead Discovery Centre to test for and identify potential pharmaceuticals that can be used to treat cancer. NiCoLA-B autonomously performs highly complex experiments, monitoring chemical interactions and checking for potential molecular activity that could indicate a promising new drug. “We can configure NiCoLA-B to do our experiments in whatever way we want and we can interact with it while it’s working. It can sense our presence in a way that previous robots couldn’t, so it can share our workspace instead of being encased behind safety guarding.” —Paul Harper, Associate Principal Scientist, AstraZeneca[48]

Case study

Flexlab

Located in Berkeley, California, Flexlab is an advanced building technologies test facility. The building is purpose-built to allow researchers to test and monitor the latest technologies in building efficiency, such as HVAC systems, windows and building envelope, lighting and electrical. Flexlab replicates real-world building conditions and includes a rotating test bed to model sun exposure from different positions.[49]

Case study

Edge Mobile App

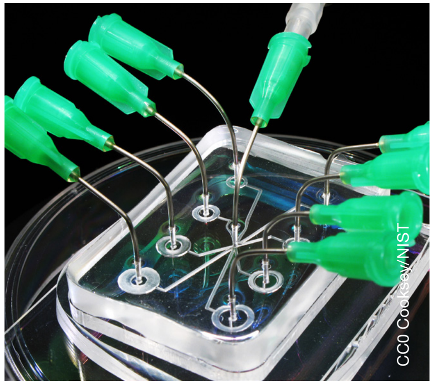
Developed by MapIQ, the Edge app puts building services at the fingertips of staff and visitors at Deloitte’s headquarters in the Netherlands. The app allows facility managers to access the building’s intelligent management systems, monitoring occupancy and usage patterns to make adjustments that save energy. The Edge offers a personalised user experience for building occupants, assigning staff their daily work stations, and allowing them to control local lighting and heating.[50]

Digital instruments that setup, run, capture and analyse experiments with limited human intervention will change the way scientists interact with lab equipment and use space. Lab equipment that once took up an entire room can now be run on software and instruments the size of a flash drive. In some cases, lab equipment may be replaced entirely by digital tools that run experiments virtually in the cloud.[31] As a result, scientists may find themselves spending less time working in traditional lab environments and more time focused on desk-based activities such as analysis and collaborative tasks. Access and movement between these environments are key considerations in designing future research facilities based on collaboration and cross-disciplinary work.[32]

Smart technologies are also transforming manufacturing in labs, especially in the pharmaceutical business, cutting production times and creating cost savings. Mass customisation and personalisation in medical care are likely to become more common, where pharmaceuticals will be manufactured according to individual profiles in factory-like lab spaces. It is possible to imagine a future where 3D printing and bio-technology converge to allow scientists to offer customised, point-of-care and direct-to-patient products such as medical devices for surgery, customised medicine or even 3D-printed tissues.[33]

Case study

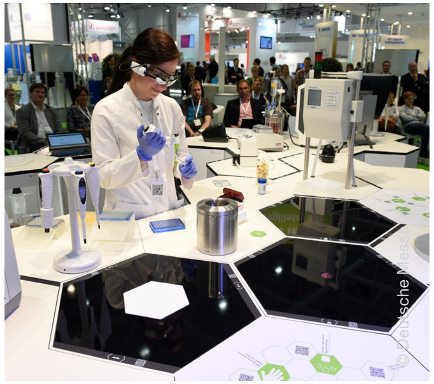
A lab-on-a-chip



A lab-on-a-chip (LOC) is a device that incorporates individual or multiple laboratory functions onto a single integrated circuit (commonly called a 'chip') ranging in size from millimetres to a few square centimetres. LOC technology can handle extremely small fluid volumes allowing researchers to scale down lab processes leading to more control over the experiment, faster response times, and greater safety. LOCs can be connected to digital lab information management systems to automatically upload test results and enabled faster analysis.[51]

Case study

smartLAB at LABVOLUTION



The smartLAB is a model and testbed for the smart lab of the future staged at LABVOLUTION, the European trade fair for innovative lab equipment and lab workflow optimisation. The smartLAB brings together a number of cutting edge use cases in lab automation into a single exhibit to assess the benefits and opportunities provided by robotics, information technology, human-machine interaction and the lessons of big data within the lab environment. The exhibit hosted daily demonstrations and forums with collaborating partners and leading thinkers in the field.[52]

Building systems and operations

Though not unique to labs, there is a trend towards the development of automated and intelligent building systems. Intelligent buildings use information captured from sensors to monitor, analyse and communicate details about their occupancy, utilities and other services. They can respond to building usage patterns and adjust themselves automatically.

Intelligent building systems produce data that can be analysed and compared with building occupancy and usage patterns to produce further insights and opportunities for optimisation and cost savings. They can provide facility managers with a centralised 'dashboard' view of all building systems simultaneously allowing for a proactive approach to oversight, maintenance and repairs.

Monitoring of building systems is not only critical for facility management teams, but for researchers themselves who need to keep a close eye on experiments or monitor lab instruments remotely. Sensitive experiments that require the maintenance of critical temperatures or processes that take several days to execute can now be monitored remotely using cloud and web-based technologies. Being able to integrate this monitoring function into an intelligent building services dashboard would help scientists save time and minimise disruptions.

A growing trend in this space is the adoption of 'lean' manufacturing methods and its effect on the design of labs. Lean labs focus on optimising laboratory processes and the way people, information and materials move through the lab spaces.[34] Lean design principles include the elimination of lab separations to facilitate the sharing of workload, equipment and resources and the central location of equipment. Furthermore, data entry and analysis desks that are integrated in the test area to support real-time data analysis and a move away from personal ownership of lab equipment, bench spaces and desks towards sharing or on-demand models.[35]

Environment-positive facilities

As for other commercial or institutional buildings, green building design for labs include passive design principles, green walls and roofs, smart energy management and water recycling, amongst others. However, labs often place increased demands on energy and house operations that produce hazardous waste materials. Some speciality labs, such as cleanrooms or lab spaces with large process loads, can consume up to one hundred times the energy of a comparably-sized commercial structure. To a large extent, safety requirements and building codes, for example around ventilation rates, and energy demand of lab equipment drive this demand.[36]

Case study

Ogilvie Building

© Martine Hamilton Knight Photography

The Ogilvie Building is a three-storey, 4,600m^2 new-build DNA sequencing laboratory and office space, located on Wellcome Trust's Genome Campus in Cambridgeshire, UK. The building was designed in a highly flexible manner, with a core services infrastructure repeated on each level, consolidated into 'service wings'. All benching is designed to be fully mobile, and service wings are located in each planning grid, allowing plug and play adaptability. This approach allows users to quickly reconfigure the space as research focus and technology requirements change.[53]

Case study

Plus Ultra Building

© Stijn Poelstra. Courtesy of Wiegerinck

Kadans Science Partner offers total service packages to knowledge-intensive institutes, including workspace, facilities and financing, with a focus on sustainable buildings. The Plus Ultra Building at Wageningen Campus in the Netherlands, for example, acts as a hub for startups and knowledge intensive businesses and institutes. Plus Ultra comprises 7,500m^2 of facilities including labs, multifunctional research facilities, conference rooms and offices. Throughout the development, user requirements can be incorporated, and customisation remains possible also after the building is delivered.[54,55]

© Matthew Millman Photography, courtesy of Flansburgh Architects

Case study

Energy Lab Hawai'i Prep Academy

The Energy Lab at Hawai'i Preparatory Academy is a purpose-built educational facility by Flansburgh Architects and BuroHappold Engineering. The building provides space for students to study renewable energy and sustainable living systems. The building is fully-powered by alternative energy sources. It achieved LEED Platinum certification and meets the Living Building Challenge standards. The sustainable management of water, energy, waste and other systems on-site creates a unique building and landscape that students can study and learn from in-situ.[56]

Managing the environmental externalities of labs, especially around waste, is critical for the safety of people and the health of the environment.[37] Designing building systems that reduce waste and recycle resources can be achieved by considering the total lifecycle of a building's materials and operations. For example, building layers can be designed to allow for easy deconstruction, separation and expansion in order to allow for changing functions, repairs and upgrades over time.

Building and operating labs in environmentally sustainable ways can also have a positive impact on the health and wellbeing of occupants and contribute to productivity and performance. This can be achieved, for example, through increasing access to natural light and using plants to improve indoor air-quality and create aesthetically pleasing environments.[38,39]

In the long-term, healthy buildings could become a key differentiator and essential component for attracting and retaining staff. Laboratories have an opportunity to become test-beds for researching green building design principles, using smart technologies such as sensors that measure air quality and building performance in real-time.

Data management and security

For research organisations, the ability to collect and analyse data is essential. Yet the sheer volume of data produced makes storage a key problem.[40] Processing this data is another challenge and running analysis on large data sets requires immense computing power. Not all research institutions are equipped to store or process this volume of data in-house. Likewise, the ability to upload and access this data regardless of location is another consideration.

To address this, researchers are embracing cloud storage technology for their data management. Many commercial cloud service providers, such as IBM, Microsoft, Google and Amazon, are now targeting their services specifically to the scientific market. In addition to offering storage and collaboration solutions, the cloud can also be used to analyse data using virtual software and applications. Cloud service providers offer researchers access to processing speeds that would not be possible in-house, allowing for complex analysis of data critical for fields such as genetics.[41]

The digitalisation of scientific research also has implications for shared infrastructure that is more intangible. For example, the creation of common data standards in science are critical for sharing and analysing data from different sources and fields.[42] In terms of data security, new technologies such as blockchain can offer unprecedented levels of stability for sensitive and valuable research information.

Blockchain-based systems allow researchers to verifiably and audit-safe prove that a specific piece of information was created by them (proof-of-ownership) or that it existed at a specific point in time (proof-of-existence).[43,44]

Case study

Novartis Vaccines Division

In 2010, the Novartis Vaccines Division (NV&D) began a structured implementation of 'lean' principles in its quality control laboratories with the aim of significantly improving internal work processes, communications, customer interfaces and operational performance.

Analysts have been trained in basic Lean principles, followed by the introduction of '5S' (a workplace organisation methodology), Visual Management for daily and weekly performance review, and finally the gradual implementation of effectiveness tools for capacity management and budget processes. Lean principles were applied in both older legacy facilities and newer state-of-the art facilities.

Throughout the Lean Lab program in NV&D it was clear that laboratory design and layout has a strong influence on processes, behaviours and communications.[57]

Case study

Open Science Data Cloud

The Open Science Data Cloud (OSDC) enables the storing, sharing, and analysing of large scientific datasets. The OSDC hosts a 'Data Commons' which allows researchers to share and access publicly-available datasets.

The Data Commons service includes data from sources such as the US Census, Project Gutenberg and the 1000 Genomes Project. In addition, researchers can access virtual machines to upload and analyse datasets, taking advantage of the computational power needed to process large volumes of data.

The OSDC is operated through the Center for Data Intensive Science (CDIS) at the University of Chicago in collaboration with the Open Commons Consortium, a not for profit organisation.[58]

Case study

Standards in Lab Automation (SiLA)

The Standards in Lab Automation (SiLA) consortium was founded in 2008 by software and hardware suppliers in the pharmaceutical and biotechnology industry to develop data and device standards for lab automation systems. SiLA standards define how information is packaged and communicated from one system to another, setting the language, structure and data types required for seamless integration between systems.[59]

Case study

POEX Blockchain Certification Service

The poex.io data certification service allows any research institution to register documents on the secure bitcoin blockchain without having to upload or publicise its content. This means that anyone can prove the existence of a document or piece of digital information before it is published, giving the original author the ability to protect his or her work from intellectual property fraud.[60]

While a blockchain is not an efficient way to store large amounts of data it is a secure and tamper-proof way to store unique digests (hashes) of a piece of information. This can be compared to a fingerprint or DNA database. Built upon a decentralised network of computers (nodes) run by voluntary and incentivised market participants, blockchain-based systems have no one authority that could act as a single point of failure.

This avoids the problems of hacking, data manipulation and data theft found in other databases.[45] Blockchain systems achieve their high level of data security through a combination of the sheer distribution of data across thousands of physical locations and an additional layer composed of computational processing power securing the data.

To be successful, a malicious attacker would have to redo the vast amount of processing work made since an entry. Beyond this, the blockchain's decentralised nature renders this impossible, as every participant in the network validates the information for themselves and would immediately recognise any manipulation before it could propagate.

Spaces and operation

Key takeaways

Flexibility and adaptability	Design laboratories and building systems that allow for changing functions and uses over time. This includes mobile benching and structural grid dimensions that enable the creation of different environments.
Plug and Play utilities	Service labs with a regular utility infrastructure that supports flexibility and allows spaces to be reconfigured with ease.
Automation	Embrace automation with digital instruments that can simplify workflows and allow researchers to conduct experiments, analyse results, share findings and collaborate on discoveries in new ways.
Intelligent buildings	Integrate intelligent building systems into labs to gain insight into usage patterns and manage utilities and services in a more cost effective and energy efficient way.
Data management and security	Proactively manage data storage, processing and security issues by considering cloud computing options and weighing the benefits of on-site management against cloud services.

Infrastructure and place

At the largest scale, this section examines the influence infrastructure and place will have on the changing roles of research and its facilities in the future. This includes advances in digital infrastructure networks that could enable new forms of collaboration across industries and geographies, and how future research facilities will shape and interact with the contextual and social fabric in which they reside.

Infrastructure for innovation

Traditionally, infrastructure for science has been geared to the physical needs of research: lab instruments, housed in buildings on campuses, served by utilities. However, as science becomes more digitally augmented and spatially decentralised, new kinds of research facilities and technologies are emerging that change how and where scientists work. This means looking beyond the laboratory footprint and hard building services to consider the wider network of systems, services and environments that support innovation. In this, virtual proximity — robust data infrastructure spanning the globe — will begin to complement physical proximity, in some cases even replacing it. Infrastructure needs to function as a 'shared platform' that enables researchers from around the world to collaborate and share resources in new ways.

Case study

European Grid Infrastructure

Established in 2001, European Grid Infrastructure (EGI) is a federation of 21 cloud providers and hundreds of data centres, spread across Europe and the world who pool their resources to provide computing infrastructure for scientists and multinational research projects. EGI is critical for science in Europe and internationally and has helped power computing for world-leading research projects such as CERN. EGI allows researchers to execute thousands of computational tasks to analyse large datasets, store and share data on a global scale, and run virtual machines in the cloud to analyse data.[67]

Case study

Glasgow City Demonstrator

In 2013, Glasgow received £24 million in UK government funding to develop and test digital infrastructure to help make the city safer, smarter and more sustainable. Glasgow became a testing-ground for the deployment of projects including street lights controlled by sensors that adjust to pedestrians and collect data on air quality and footfall, road sensors operated by computers that read and analyse traffic flows to adjust traffic lights to improve traffic, and an open data portal to make this data and more than 300 other datasets freely available for researchers and the public.[68]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Case study

PARC Paris

The new building at the Université Pierre et Marie Curie in Paris is intended to bring together researchers from different disciplines, startups and established companies under one roof. Areas of the building will be open to the public, including a rooftop laid out as a park. The stairway leading to the roof terrace will allow visitors to see into the labs and witness their everyday activities. The divisions between the labs will also be transparent to ensure a visual link between different workplaces. In addition, the ground floor will hold a public bookshop, a café and exhibition areas.[69]

Case study

University City Science Centre

Founded in 1963, University City Science Centre (UCSC) was the first urban innovation district established in the US by founding partners Drexel and Temple University, Philadelphia College of Pharmacy and Science, and Presbyterian Hospital. UCSC provides business incubation, lab and office facilities, and support services for entrepreneurs, startups and growing companies in the medical sciences. Its flagship business incubator programme has launched 442 companies, 155 of which remain in Philadelphia contributing nearly US$13 billion in annual economic activity to the region.[70]

Urban research clusters

The geography of innovation is shifting from suburban research parks and university campuses to urban innovation districts that bring established research institutions and companies together with technology startups and creative industries.[61] Urban innovation districts provide physical infrastructure and programmes to support collaborative research and commercialisation activities that transcend boundaries and disciplines.

Urban innovation districts are not a new phenomenon, but they are becoming a more common way for universities looking to translate knowledge into industry and for businesses looking to take advantage of cutting edge R&D opportunities.[62] Innovation districts provide a full-service pipeline for fast moving ideas from the discovery phase through to testing and commercial or real-world applications.

The most successful urban innovation districts support research and commercialisation activities by offering promising start-ups resources in the form of physical space, mentorship and funding. Access to state-of-the-art research facilities, deep talent pools, and local and international business markets make the urban innovation district a compelling place to start or scale-up a business and conduct leading edge research. Access to talent and capital is not the only advantage that urban innovation districts can offer — the urban environment itself can become a resource for research and experimentation. Urban districts can become a 'living lab' for research into technologies that have a social or spatial dimension especially in the areas of machine learning, automated technologies and the internet of things (IoT).[63]

Science parks

Despite the shift to urban innovation districts, suburban parks remain a popular and important venue for research and innovation. From Silicon Valley in California

Case study

MaRS Discovery District

MaRS Discovery District in Toronto is one of the world's largest urban innovation hubs. It assists companies in accessing networks and venture capital. The campus is located in Downtown Toronto adjacent to the University of Toronto, the University Health Network, major hospitals and health science research institutions. Tenants are AutoDesk and Facebook, along with small and medium-sized businesses across advanced health technologies, digital media, green energy and water technologies, agriculture, forestry, materials, advanced manufacturing, nanotechnology and financial services.[71]

Case study

Wellcome Trust Genome Campus

The Wellcome Genome Campus in Cambridgeshire is a world-leading research centre in genomics and biodata and one of the key locations where the human genome was mapped. In 2018, the campus undertook an expansion planning process to provide new research facilities, amenities for staff and space to translate research discoveries into real-world commercial applications. The emerging vision for the campus is a neighbourhood model that not only provides space for research, it also includes housing, public open space and connections with the wider community.[72]

Case study

Urban Campsite

Urban Campsite is an open-air exhibition and pop-up camping experience that activates under-utilised urban sites in Amsterdam. The 2017 edition, titled The Art of Tech Living, was located in the Amsterdam Science Park and included structures that provoked conversations about issues at the intersection of science, art and the environment. The Science Park location, one of Europe's largest hubs for research and innovation in beta sciences, provided a venue where researchers and artists could interact with the public to promote greater understanding and engagement with science.[73]

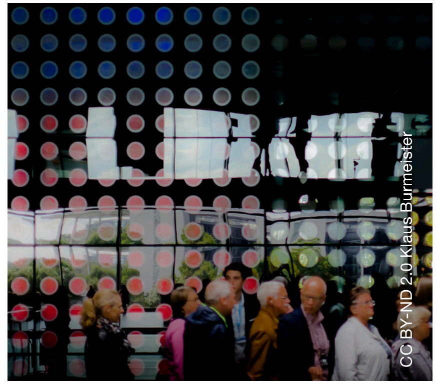
Case study

Facebook Menlo Park

Facebook is building a new mixed-use campus across the street from its Frank Gehry-designed headquarters in Menlo Park. Dubbed "Willow Village" the campus will include a mix of residential, commercial and open space along with new office and research facilities for Facebook. The scheme will include a minimum of 1,500 housing units, including at least 225 below market rate; 126,500 square feet of retail including a grocery store and pharmacy; 200 hotel rooms; and 18 acres of open space, of which eight are to be publicly accessible.[74]

Case study

Futurium Berlin



The Futurium in Berlin has been built to host events and exhibitions that showcase possible scenarios on the changing shape of life. Particular emphasis is to be placed on the impact of research and innovation. The innovative building will also provide a forum for dialogue on the future in which not only scientists, business leaders and politicians but also citizens can actively participate.[75]

to Research Triangle Park in North Carolina, a 2017 study of patents filed in the U.S. between 2000 and 2010 found that more than 40 per cent of patents came from places that had a density below 2,500 people per square mile — in other words, suburban areas.[64] The model of the suburban science park has remained largely unchanged from the template established in the mid-twentieth century: low density collections of buildings set in a manicured campus environment, linked to adjacent research institutions and residential communities by highways.

As science becomes more complex, interdisciplinary, international and digitally augmented, science parks will need to reflect these changes. The tranquillity and cloistered isolation of a campus may be useful for some forms of research, however as innovation becomes increasingly reliant on collaboration, networks, informal exchanges, and the ability to rapidly incubate, test and deploy ideas, suburban science parks will need to evolve. The transformation of suburban science parks into a model that more closely resembles urban clusters is a trend that is set to continue. Science parks might take on urban forms and support a greater diversity of uses and interactions.[65] We can see this trend already starting to emerge as corporate giants like Google and Facebook remodel their corporate campuses into self-contained cities with housing, retail, open spaces and transit in the mix. The challenge for this campus-style developments is around placemaking and the creation of a community, providing spaces for social encounters, creating a sense of belonging and encouraging scientific interactions.

Labs as social and public benefit

Science has revolutionised every aspect of our modern world, yet despite the scale of its impact, science enjoys a relatively limited public profile. Countering this, there is a growing trend towards increasing public awareness and engagement with science, and laboratories are at the heart of this. Labs, especially those located in accessible urban areas, are increasingly being designed with public benefit in mind. New research facilities often include public atriums and cafes inviting guests to sit, socialise and work. Lab buildings in urban areas are often designed with a high degree of transparent glass, literally inviting the public to peek inside to see science at work from street level.[66] Inside the building, public programming in the form of lectures and exhibitions that present science in exciting and accessible ways are now common at large publicly-funded research facilities.

The living lab is another significant development, where labs have become an important form of social and public infrastructure. Living labs extend the lab beyond the building into the fabric of the city, using the urban environment as a testbed for experiments, often in the digital and tech realm. There are living labs for testing smart urban infrastructure, green solutions for cities, the deployment of IoT and autonomous vehicles, amongst others.

Infrastructure and place

Key takeaways

Shared digital infrastructure
As science becomes more digitised and distributed, shared infrastructure such as cloud computing and web-based platforms are needed to enable researchers to collaborate and share resources in new ways.

Cities as platforms for innovation
Access to advanced transportation and communications infrastructure, state of the art research facilities, deep talent pools, and international business markets make cities the ultimate platform for innovation.

Urban innovation districts
The co-location of large research institutions with startups and co-working hubs in cities provides researchers with a full-service pipeline for moving ideas from discovery to real-world applications.

Science parks re-imagined
Suburban and regional science parks are being re-imagined and redeveloped into more complete communities with housing, public open space, transit access and connections to the wider community.

Living labs
Using the urban environment as a ‘living lab’ for research and experimentation can help researchers gain real-life insights and promote greater levels of public engagement with science.

Science and placemaking

Malcolm Smith
Arup Fellow,
Integrated City Planning

The contemporary lifecycle of the scientific process is so much more than the old image of white coats in labs. Today it is a journey from discovery and innovation, through testing and commercial translation, to full commercialisation and implementation. Such a broad lifecycle is populated by a diverse range of people. And, in the ever-increasing growth of the science sector, the highly skilled people who energise the system are increasingly in demand and therefore competed for. As such, they are able to expect and ask for not only career and commercial outcomes, but a broader quality of life for themselves and their families. It is the role of the location of science ecosystems to address both the technical requirements and the lifestyle needs, if places of science are to be competitive and therefore successful.

The wider ecosystem — of research and discovery, translation, commercialisation and complementary lifestyle — also requires convenient and efficient connectivity. This has to be both physical and non-physical. Physically, it ranges from immediate adjacency, to regional connectivity and relationships, with easy international connectivity through rail or air. Yet connectivity must also be non-physical — primarily through digital connectivity. Highly-resilient digital connectivity and capacity is fundamental to desirable science location.

The different parts of the science ecosystem each have their own characteristics which contribute to the contemporary needs of places of science: at the core of the ecosystem sits research and discovery.

Research and discovery

The place of research and discovery, where ground-breaking ideas are conceived and explored, is actually three different types of place.

- *Place of creative interaction:* This is a place of interaction, sometimes planned but often informal, between people of diverse science expertise and experience. A great café or sports facility can be a place of serendipitous discovery and invention, facilitating opportunities to bump into someone.

- *Place of wandering:* This is a place often forgotten in contemporary urban thinking. It is a place of quiet reflection and contemplation. Such places can be as simple as a walk through a park or a beautiful place in the sun to read. When Newton discovered gravity, he was sitting under a tree, not in a coffee shop!

- *Place of social interaction:* Discovery benefits from occasionally positioning itself within a wider community not related to science. This diverse social cross-section creates environments of removal from day to day considerations, and allows the subconscious mind to work.

Places of translation

Places of translation are interstitial places. They work best adjacent to places of discovery science, as the people of translation often are the people of discovery. These places need to change quickly, in size, use and changeover.

Places of commercialisation

As science deploys into the market, it requires spaces of organisation, manufacture and logistics. Places of science commercialisation must integrate the characteristics of the contemporary workplace, offering a range of environments that facilitate thriving workplaces.

Complementary community

Sitting next to the science ecosystem are the components that contribute to an overall quality of life. This may be access to affordable housing or social amenities such as schools, medical care, recreation, ease of transport and culture. Whether located directly adjacent the science facilities, or as part of an accessible network, the complementary community is becoming a critical factor in the decision on where the highly skilled science community chooses to work. So, the place of contemporary science has many diverse expectations. The locational attributes range from technical performance to what makes high quality places. We believe that to develop tomorrow's places of science, a clear understanding of the science ecosystem and its inter-relationships is required, resonating with the idea of total design that underpins Arup's approach.

Towards a new research ecosystem

The future of scientific research facilities is increasingly shaped by a focus on collaboration, flexibility and a more open approach to science, both physically and intellectually. Research is becoming more multifaceted and more accessible to a range of scientists and civilians. Future lab design needs to include and allow for as many usages as possible, while still making room for individual needs. This seeming conflict of interests can be addressed through intelligent building design, digitalisation and automation. Designers, contractors and other stakeholders need to consider the use of intelligent systems and services and assess their impact on the project at hand.

Envisioning the future of scientific laboratories and their accompanying service facilities, stakeholders will have to focus on two main themes: user friendliness and integration into the urban ecosystem. Research designs and outcomes need to be distributed among civil society, seeing them as an asset not a burden to integrated understanding of processes.

Being user-friendly will have to encompass a wide range of services and design solutions. Spaces need to be adaptable to differing user needs. Workflows need to be designed efficiently, while not sparing quality, through the use of automation and artificial intelligence. Quality of stay should be increased in and around research spaces wherever possible, attracting employees and improving the public realm for all through placemaking and interactive spaces. Indoor and outdoor greenery needs to be a core element of spatial design, rather than a later addition. Lab spaces and their surroundings can transform into a vital and buzzing zone for interaction across the city and beyond.

This report has provided an overview of key trends and developments shaping the future of scientific research spaces. On the following pages, a series of elements that will likely make up the future scientific research ecosystem are highlighted, followed by a summary of implications and actions across people, spaces and infrastructure.

Left: The Sainsbury Wellcome Neuroscience Lab in London features a colonnade to engage with the streetscape and wider public


THE RESEARCH ECOSYSTEM
Internet of Labs
Cloud Labs
Interaction Spaces
Science Canteen
Labs as Office Spaces
Healthy Spaces
Non-Urban Labs
Intelligent Spaces
Human-Robot Interaction
Plug and Play Spaces
DIY Labs
Tool-Centric Spaces
Everywhere Labs
Outdoor Spaces
Accessible Science
Connected Spaces
Everywhere Labs
Activated Spaces
Pop-Up Labs
© Arup

People and collaboration

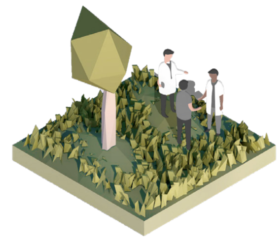
Labs as office spaces
Lab spaces are increasingly designed like office spaces. Space layouts tend to be more generic, serving a range of functions across disciplines and activities. Activity-based workspaces alternate with more open spaces for interaction. Flexible and modular furniture, such as height-adjustable desks and wall segments, plus storage spaces for a 'clean desks' set-up, allow for fruitful interaction and an optimum use of space. In addition, more private 'quiet spaces' offer options for highly-focused work.

Science canteen
The canteen can act as an informal meeting and food space all in one. Employees can recharge their batteries and interact with colleagues from other disciplines. Outdoor seating promotes a healthy working environment. The space allows for different kinds of interaction, private conversation or public events alike. Furthermore, food options can be complemented through personalised meal options or nutrition tracking included in the space.

Interaction spaces
Interaction spaces provide options for interdisciplinary team work as well as chance encounters. This can be assisted through flexible furniture design and space layout for options to discuss, present, sketch and model processes and ideas. While some spaces offer privacy, others promote communication through visual and acoustic relations with the surrounding work environment. Interaction spaces provide a counterbalance to highly-focused work environments.

Healthy spaces
Health-promoting spaces consider workspace conditions, including indoor air quality, daylight levels, connection to nature — indoor and outdoor — as well as personal control. Workspaces can be designed to be adjustable in order to cater to differing needs. This includes amongst others, height adjustable desks and chairs, individual light controls and measures for noise control. Visual connections across space and to outdoor greenery additionally increase wellbeing.

Outdoor spaces
Including outdoor spaces as a vital part of research facilities can significantly increase occupants' health and wellbeing. Green outdoor spaces function as recreational and recharging spaces while also improving local microclimates. Spending quality time outside also improves physical health, triggering movement from a routine work position and exposure to sunlight and fresh air. Spending time outside improves mental health as well, offering distance from stressful situations in a calming environment.



DIY labs
As the science sector equivalent to FabLabs or Maker Spaces, DIY labs allow the public to take part in research, try out things and get access to science. Such labs can become part of larger research facilities and thus offer the general public access to resources, tools and materials, space and scientists. DIY labs can help to bridge the traditional gap between research institutions and civil society.

Spaces and operation

Cloud-based labs

Cloud-based or virtual labs are automated research and testing facilities that can be accessed via the cloud. They allow researchers to remotely access the facility and design and run experiments. Cloud-based labs can be offered as on-demand features, thus decreasing costs for researches and institutions alike. The automation of workflows eliminates the need for human intervention and scientists can remotely run several experiments in parallel from any location.

Human-robot interaction

In contrast to fully automated facilities, spaces that are designed to accommodate robots alongside workers allow for immediate interactions. While the deployed robots can still autonomously perform experiments, humans also get the chance to interact with the robot in real-time during the working process. The robot can thus respond to interactions, speeding up laboratory processes while working alongside and collaborating with scientists.

Plug and play spaces

Plug and play spaces are spaces designed to facilitate a wide range of activities, thus catering to differing and changing needs. Modular furniture, floor layout and ceiling grids allow for flexibility and easy reconfiguration. Floors are usually kept free of obstacles to allow for maximum flexibility. Individuals can adjust the spaces to suit their requirements — this can even happen hourly or daily.

Tool-centric spaces

Tool-centric spaces are designed around equipment rather than discipline. As such, these spaces can provide a large group of scientists with highly specialised tools and equipment. Designing spaces around equipment can increase the utilisation time and reduce costs and space requirements, as not every department has to provide the same equipment.

Intelligent spaces

Intelligently managed spaces can improve the allocation of available spaces and rooms through analysing usage patterns and managing resource use. Additionally, based on user patterns and individual controls, occupants have a greater freedom to adjust their working environment, including lighting and temperature settings. Facility management and maintenance needs can be monitored more accurately, carried out through automation and robotics.

Pop-up labs

Pop-up labs are mobile and flexible research spaces. They can be set up in any context and bring science, or the lab space, to the general public. Pop-up labs can function as learning and education hubs, facilitating events and discussions, thus enabling access to science across demography and geography. Furthermore, pop-up labs can provide scientists with a space to conduct experiments in real-life conditions outside the lab environment.

Infrastructure and place

Internet of labs

The Internet of Labs describes the digital/non-physical infrastructure that enables connectivity and collaboration across spaces and regions. This digital infrastructure connects a network of research spaces in a variety of locations — from private homes and research clusters in urban spaces to non-urban science parks. Thus, science is not limited by physical proximity anymore, but can happen remotely and simultaneously across the globe.

Everywhere labs

Everywhere labs are decentralised lab spaces, often in non-lab facilities. This could be a private home or a co-working space. Thanks to digital networks, research can happen anywhere at any time, and previously isolated places can become part of larger research clusters. This also encourages community-research where living rooms can now be part of the global research ecosystem.

Non-urban labs

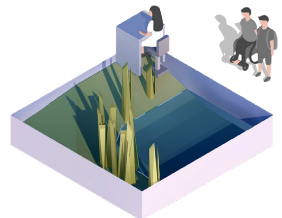
Non-urban labs constitute research clusters, science parks and campuses outside the city — a development that continues to happen in parallel to urban research clusters. Non-urban science parks are able to cater to requirements that urban areas might not be able to fulfil. This includes, for example, the spatial needs of large-scale research units as well as specialised equipment and activities that need to take place in a more remote location.

Accessible science

Science is no longer exclusively happening in isolated, closed off institutions. Accessibility and visibility of scientific endeavours are becoming more important. As such, research institutions are opening up to the public through including event and exhibition spaces that enable the exchange of knowledge and ideas. Increasing importance is placed on public realm qualities around institutions to engage with the public, and the facilitation of easy and open access to the institution itself.

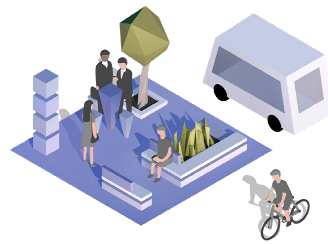
Activated spaces

Research activities hold the potential to activate in-between spaces across the urban realm. Through Living Labs or real-life test beds, research activities spread to public spaces. Spaces are activated, the public realm is improved, interaction with the public is facilitated and testing and experimentation can happen outside the research facility. Distributed activated spaces can also act as connectors between various research institutions across the city.



Connected spaces

Mobility and accessibility — the physical network — are as much part of the urban science ecosystem as the non-physical digital network connecting the various elements. Accessibility can be enhanced through integrating different modes of transport that connect research facilities across the city, making mobility one of the most important enablers for interaction and participation. Accessibility, including through active and public transport, is key for the efficient organisation of distributed research spaces.



Actions and recommendations

People and collaboration: human experience and needs

Highly diverse users and user groups of laboratories increase the need for adaptable spaces and flexible configurations. At the same time, productivity, comfort, ease of use and spaces for interaction and collaboration are fundamental for the successful functioning of research spaces. Considerations around exchange and chance encounters, privacy, health and work-life balance — all part of the human experience — need to be considered in the design and location of labs.

- Design flexible workplaces that enable easy adaptation to suit different needs
- Include informal, easily-accessible spaces to enable cross-disciplinary interaction, exchange, collaboration
- Use outdoor greenery and biophilic interior design to support healthy work environments and enhance wellbeing
- Engage the public through temporary DIY labs across the cityscape, and make knowledge accessible via open source clouds
- Invest in digital skills, with training courses and public engagement open to all
- Consider user demographics, disciplines and future demands from an early stage

Spaces and operation: flexible and responsive systems

Seamless operation of parallel functions and uses need to be well organised. Physically, lab spaces need to be modular in order to adapt to the differing needs of researchers and public audiences. Digitally, automation and artificial intelligence can improve workflows and user experiences. Lab spaces need to be connected via cloud-based services, enabling data processing and communication as much as (remote) experimenting.

- Create a flexible, generic set-up of lab grids and equipment to enable easy alteration according to changing routines
- Use digital solutions to connect labs to cloud-based services and communication
- Design spaces that support automated workflows and services, while incorporating human-centric usage
- Include artificial intelligence in the design of workplace layouts, optimising its use in space allocation, maintenance and human-robot collaboration
- Open science to the public, with intertwined research labs and public spaces, events, accessible areas and DIY spaces

Infrastructure and place: context and integrated design

Digitalisation enables the decentralisation of science across spatial borders. The dissemination of knowledge to society is facilitated and experiments can happen across facilities. Physically, labs should be designed with permeability in mind, to allow for interaction and discussion. The lab's location within the cityscape has to take into consideration factors such as closeness to national and international transport hubs, interaction with public space, housing or social infrastructure.

- Broaden the understanding of where research happens, using the wider cityscape as an innovation platform
- Consider decentralising lab spaces to increase collaboration and connectivity to other institutions
- Locate research spaces across the city, making use of non-science related services
- Enable interaction with the public by activating the public realm in and around lab spaces
- Design inclusive and accessible indoor and outdoor spaces, including mobility options and connections

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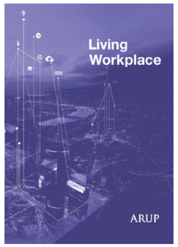
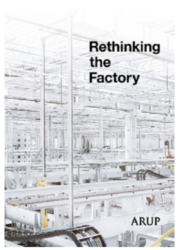
Publications

Campus of the Future examines the trends affecting the design, operation and experience of higher education campuses, highlighting global best practices from the education sector and beyond. It aims to help higher education designers, developers and facilities managers better understand the forces shaping these evolving spaces.

Future of Libraries examines the key trends that are influencing the transformation of libraries in terms of the social infrastructure they provide and the services they offer. Libraries are evolving into hubs for education, health, entertainment and work. They are becoming strategic city assets, designed to stimulate cultural exchange, economic prosperity, and support stronger communities.



Living workplace considers a broad spectrum of research and trends relevant to this transforming typology, including digital services, emerging business models and workforce wellbeing. By analysing what aspects need immediate attention and action, the report aims to help developers, tenants and designers better understand the forces shaping the workplace of the future.



Rethinking the factory describes the emerging trends, processes and technologies that will transform the manufacturing landscape. The inevitable shift to leaner, smarter and more flexible forms of production will have a range of impacts on how the factory is designed, how supply chains operate, how people experience changing operational environments and how the future spaces of production will be organised.

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About Arup

Arup is the creative force at the heart of many of the world's most prominent projects in the built environment and across industry. We offer a broad range of professional services
that combine to make a real difference to our clients and the communities in which we work.

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Founded in 1946 with an enduring set of values, our unique trust ownership fosters a distinctive culture and an intellectual independence that encourages collaborative working. This is reflected in everything we do, allowing us to develop meaningful ideas, help shape agendas and deliver results that frequently surpass the expectations of our clients.

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Science and research are key to addressing humanity's biggest challenges, now and in the future. Creating the right spaces and environments for research to thrive is essential.

The scientific research ecosystem goes far beyond the physical spaces of laboratories. Among many things, it encompasses the people making research possible, the places where scientific discoveries happen, and the infrastructure required to sustain innovation. Only by recognising the extent of this ecosystem can we begin to understand the complex interactions between its people, spaces and contexts, and how the spaces we create can respond meaningfully to these diverse requirements and desires.

This report provides a review of key trends shaping the future of scientific research that will be of use to planners, designers and administrators involved in laboratory design projects. The findings are a synthesis of research and trends in the field of laboratory design, informed by conversations with experts across industry and academia.

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