You, Me, and We: Biolabs for the 21st Century

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Twenty-first century biomedical research is advantaged by institutional infrastructures that foster a collaborative, multidisciplinary approach. A few critical elements in the design of labs, research buildings, or campus can make interaction easier while preserving privacy and comfort for the individual researcher.

The Problem

In the first decades of the 21st century, biomedical research has reached a tipping point in the requirement of an interdisciplinary approach to experimentation. Thanks to the remarkable advances of the 20th century, scientists can now study medical and chemical systems at the atomic and subatomic levels, bringing the knowledge and technology from an array of scientific disciplines to bear on the understanding of one cell or one molecule. For example, a neuron can no longer be effectively understood through the traditional techniques of biology or chemistry or neurology. A given set of experiments might require the tools and know-how of a cell biologist to understand the details of cell structure, a chemist to understand the molecular dynamics, a physicist to elucidate the electrical nature of neural transmissions, an engineer to develop a new device to detect cellular interactions, geneticists and biochemists to describe the in vivo protein reactions, a mathematician or computer scientist to write algorithms and develop equipment software.

Universities and research institutions, the very entities that enabled the development of these remarkable new capabilities, now find themselves scrambling to re-organize away from departmental models and toward collaborative, integrative forms of research. This is no slight challenge, given the enormous existing investments in buildings, campus layouts, administrative organization, and funding mechanisms, all designed for doing research in the 20th century. Increasingly, existing research facilities struggle with redundancy, fiefdoms, and physical and organizational barriers to efficient collaboration.

Where We Are Now and How We Got Here

An elite university in the 19th century might have had seven or eight departments of science, such as astronomy, biology, botany, chemistry, physics, geology, and mathematics. Usually, each department was housed in a separate building, or had its own wing in a science building. In the 20th century, an elite university had several major science schools such as a School of Medicine, School of Humanities and Sciences, and School of Engineering, with each school harboring as many as 20 departments. Interaction within a department became harder, within a school even harder and between schools almost unheard of. Not only did the physical logistics need to be managed efficiently, but separation due to distance became a major management and design issue.

The first labs (Figure 1A) were simply rooms with tables for setting up experiments, tall windows for ventilation and lighting, shelving for glassware and bottles of chemical reagents, and a sink for cleaning up. Because elements in the laboratory environment can profoundly affect the results of experiments that study individual cells and molecules, and because an experiment is only considered valid if it can be repeated by other scientists, laboratory design has developed with the aim of controlling and accurately measuring as many elements as possible. Elaborate HVAC systems, vibration-resistant structures, microbial and small particle isolation equipment, and EMF shielding are several of the numerous components integrated into standard laboratory design today. Today, safety features to contain and isolate elements that pose a risk to researchers and to the communities in which labs are situated, add to the technical requirements of laboratory design.

The current standard biolab (Figure 1B) needs outlets at the benches every 6″, refrigerators, freezers, and a myriad of table top equipment that mix, incubate, analyze, measure, sterilize, concentrate, desiccate, cool, heat, filter, combine, and freeze. The heat load from the electrical equipment is offset by sophisticated mechanical systems that can evacuate a lab in a few minutes and regulate and stabilize temperature within a degree and humidity within a percent. Because of these robust systems, ceilings can be low and often there are no exterior windows. The windows in labs that have them do not open. The concept of the standard mechanical system is that the room purity, temperature, and humidity can be controlled best if the building is sealed. So all outside air comes through large fans with air filters, usually on the roof of the building. The effluent air and water streams are usually monitored and filtered to varying degrees based on the nature of the effluent. The simple lab is now zoned with supply on one side and exhaust on another and air flow diagrams are prepared to make sure labs have proper circulation

One of the major problems generated by late 20th century research buildings is that to keep the air fresh and the appropriate temperature and humidity stable, requires exorbitant amounts of energy. As a building type, lab buildings are one of the most, if not the most, energy consumptive of all building types. Since buildings consume 40% of the energy consumed in the United States, lab buildings in the areas of the United States with high and low outside temperatures have been studied extensively to find improved

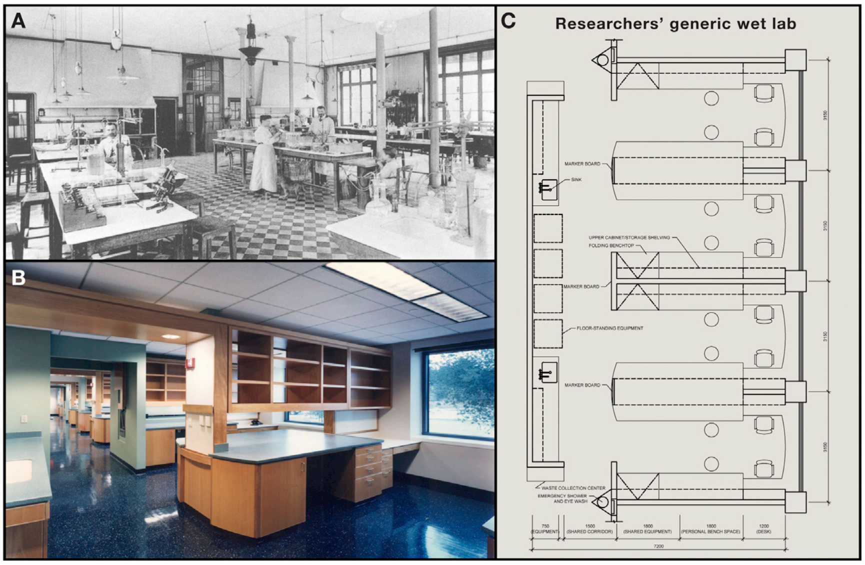

Figure 1. The Design of Research Laboratory Has Evolved Dramatically over the Years
(A) A typical 19th century lab.
(B) A current lab model.
(C) The arrangement of a generic biolab.

efficiencies in air conditioning and heating demand. A standard fume hood consumes more energy than a dozen single family homes. Many lab buildings have more than a hundred fume hoods. Fume hoods exhaust the lab air at a sufficient velocity and volume to protect the researchers from inhaling fumes from the reactions or volatile chemicals. The air that is being exhausted must be replaced with conditioned air. When the outside air temperature is 100°F or 20°F, the fume hoods are throwing out air that was just cooled down or heated up by using significant amounts of energy.

Toward the end of the 20th century when global warming became better understood, architects started studying fume hood use and then arranging labs so that hoods could be shared and the total exhaust volumes decreased. Engineers came up with new hood controls which throttle down air speed in the hoods when they are not being used. Elaborate control systems are now provided which recognize how the room pressure changes when the fume hood is at full capacity or throttled down and the total air to the room is then balanced to compensate for the air change. They are provided with motion detectors to monitor when the hood is in use, so hood placement and circulation in the lab must be controlled.

At this time in the US, the waste stream from a standard lab facility is an order of magnitude more expensive to deal with than the supply stream. Hazardous materials are managed and controlled by facilities departments, fire departments and waste handling occupies dedicated portions of labs, buildings, and campuses. If a chemical or compound costs \$10 to get to the bench, it costs \$100 to dispose of it to conform to current GLP and environmental standards.

In addition to the cumbersome and impersonal nature of large administrative entities is the aforementioned growing technical complexity of the research environment. Together, these qualities can impinge upon the simple effort of a curious person to learn about the intrigues of nature. Architects confronted with constantly expanding and changing codes and technical requirements that require coordinating combinations of specialists are prone to allow the research space to become oriented toward its technical needs rather than its purpose as an environment for curious and creative people. All too often the resulting designs focus on the accommodation of expensive equipment and complicated systems, while treating the social and humanistic needs of the people who use the buildings as a lower priority.

If the trajectory of the individual laboratory space in the 20th century has been one of increased complexity, a corresponding arc can be traced in the rise of large research campuses and universities, massing thousands of researchers at one site. University departments formed around successful scientists who attracted money and colleagues to create impressive scientific entities. Schools and departments within large universities needed money and space to continue to prosper. Once departments grew large, with correspondingly large budgets, they necessarily accrued extensive rules to regulate the use of space and the distribution of money within the institution.

The Bottom Line

Some of the most creative and remarkable research discoveries have emerged from abysmally dank, poorly designed basement laboratory spaces. But the work could have been done faster, more efficiently, and with fewer diversions if the conditions were better. In addition, there are other reasons why careful and more humanistic design is worth the effort and investment.

The prowess and effectiveness of a research institution is the quality and reputation of its faculty. The best faculty attract other excellent faculty who want to work with them. They attract the best students and are better able to secure funding. A facility that helps attract the best faculty and to retain them in a competitive field of academic talent wars is valuable. It is not a realistic expectation that a building can be the major factor for a research star to select a new place to work. However, given two relatively equal intellectual environments, the one with the better facilities often gets the upper hand.

For many years, attractive or comfortable labs or lab buildings have been an oxymoron. Now that public funding is more difficult to acquire for new buildings, private donors are sought after for financial support. They often want to have their names on buildings, lobbies, or labs and are very concerned that the facilities have an inspirational or memorable impact on the campuses, researchers,