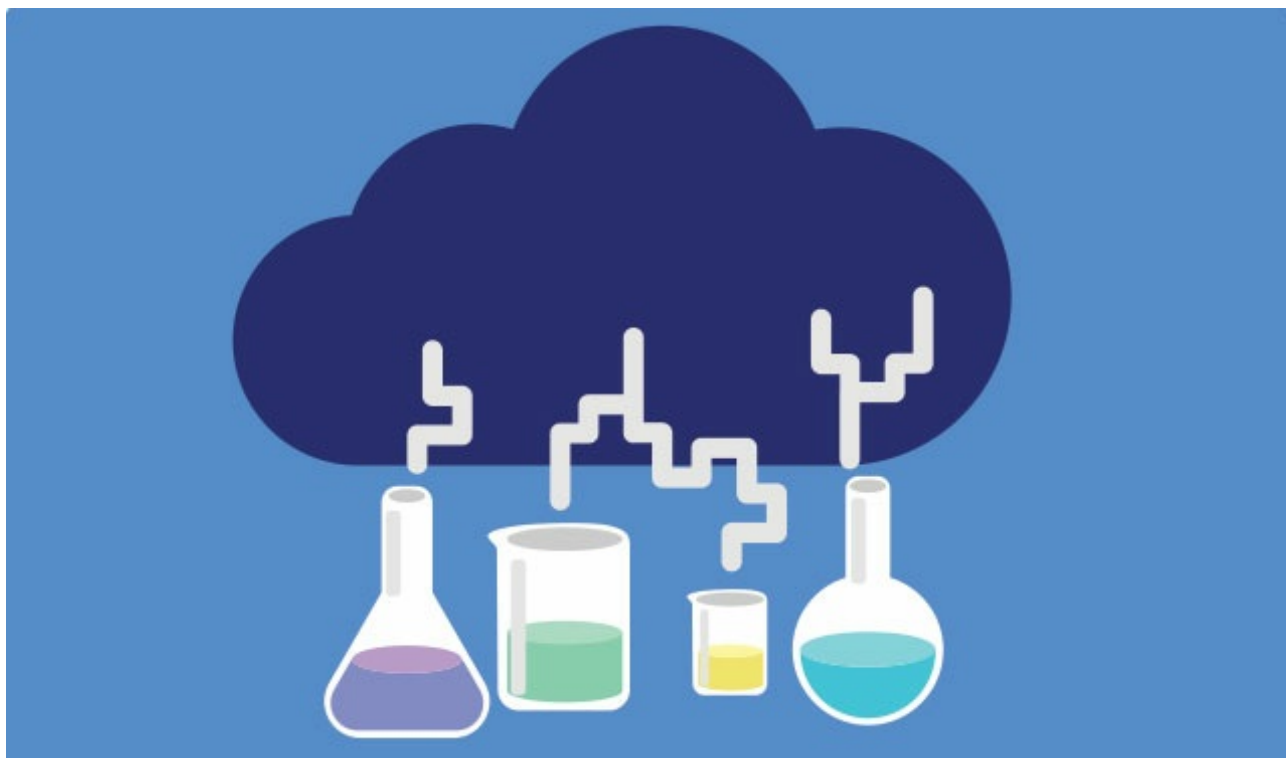


# Bringing the Internet of Things into the Lab

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The IoT can link up many facets of research—from laboratory equipment to ideas—but scientists must be ready for the questions its implementation could raise.

By Abby Olena | June 1, 2018



© ISTOCK.COM/TARIKVISION One of the two high performance liquid chromatography (HPLC) machines in [Lakshminarasimhan Pranatharthiwaran](#)'s lab at Sunovion Pharmaceuticals in Marlborough, Massachusetts, wasn't working. The instrument's readouts—a series of peaks that indicate the components of the drugs that Pranatharthiwaran's group analyzes—were jumping around all over the place.

Troubleshooting the machine and complaining to the supplier of the columns used in the instrument failed to turn up a solution. So Pranatharthiwaran's team stuck a cloud-connected temperature sensor right next to the machine in question. After several days of using an electronic lab notebook (ELN) to record the temperature readings from the device, the team identified the problem: the building's climate control system was blowing hot and cold air at specific times every day in the vicinity of the instrument. "If you happen to be running the analysis at that time: boom"—the readouts wouldn't be accurate, Pranatharthiwaran says. Once they figured out their building's temperature fluctuations, he and his group were able to get their analyses back on track.

It's a prime example of how the emerging Internet of Things (IoT)—a virtually connected network of physical devices, such as lab equipment and sensors—can help solve problems that researchers have traditionally addressed over hours or days of direct monitoring. In addition to collecting data about equipment performance and laboratory conditions, scientists such as Pranatharthiharan can use the IoT to deposit vast amounts of experimental data into the cloud directly from instruments and to control experiments remotely. “It's very clear that research in laboratories—particularly in biology and biomedicine—is becoming fully intertwined with online technologies,” says [Sabina Leonelli](#), a philosopher who studies data and life science at the University of Exeter in the U.K.

The trend is aided by a growing number of tools to gather data and metadata into the cloud. Both IoT-specific startups and larger equipment manufacturers are moving to develop cloud-based initiatives in order to grab their piece of an overall IoT market projected to grow more than threefold, to \$561 billion, by 2022. Proponents say that scientists can use network-ready tools to scrutinize lab data more closely and make connections that weren't obvious before, potentially facilitating more-efficient and more-reproducible research. But some observers emphasize the need for caution in adopting the IoT, and note that it remains to be seen how science will cope with the challenges and ethical implications of the transition to a fully connected lab.

## Getting connected

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Several startups have emerged in the last few years with the express aim of developing the IoT for laboratory use—an endeavor they say can help address the crisis of reproducibility that plagues scientific research. For instance, Massachusetts-based Elemental Machines, the company that made the temperature sensor that Pranatharthiharan used to solve his HPLC problems, offers several tools that help experimentalists stay on top of anomalies in how an instrument runs or help predict equipment failures. These include wifi-connected hardware for monitoring laboratory conditions, a device that can plug into any instrument with a data port, and an online and mobile dashboard that collects all of a team's data and metadata in one place and can send alerts to researchers.

[Sridhar Iyengar](#), Elemental Machines CEO and founder, says the company specifically focused on sensors that monitor temperature, humidity, carbon dioxide levels, light, and air pressure because those metrics are the most likely to perturb chemical reactions or biological processes. “Our mission, very broadly speaking, is to increase reproducibility in science and science-based activities,” he says.

Researchers can use the sensors to monitor more than just room conditions. In the past, chemists in Pranatharthiharan's group recorded temperature readings to track the progress of chemical reactions by standing next to the hood with their tablets and manually inputting data into their ELNs every minute or so. Now, they plug a probe into one of Elemental Machines's

sensors and the data stream straight into their ELNs. “I want to use tools that make the life of my folks a little bit easier,” says Pranatharthiharan. “Now they can just plug the stuff in and then go and do something else.”

Other companies are going further than just monitoring lab equipment; they’re offering remote control. Boston-based TetraScience is one such company. “There are all these different pieces of instrumentation and devices that produce extremely valuable data,” says [Alok Tayi](#), TetraScience CEO and cofounder. “Yet the way that data is accessed and the way those instruments are operated right now is all manual.” The firm collaborates with equipment manufacturers to integrate cloud connectivity, makes a wifi-based hardware link that can talk to sensors and simple instruments such as balances and stir plates, and provides an online dashboard that links it all together.

Chemist [Jonathan Barnes](#), now at Washington University in St. Louis, used early versions of TetraScience hardware and software for free as a beta tester during his postdoc at MIT to monitor and control polymer synthesis reactions via an app on his phone. “I could turn the stir plate off, or I could change the temperature, or just completely cut power to the entire thing,” he says. It was especially useful because the reactions were time sensitive; heated for too long, the materials would start to decompose. Without remote monitoring and control, “I couldn’t set it up at 6 or 7 o’clock because then that meant I would have to come back anywhere between 1 and 3 AM, depending on the length of the experiment,” Barnes says.

| Connecting animal research to the cloud has helped minimize stress on lab organisms.

In some cases, the IoT can provide immediate feedback to researchers using connected equipment. University of California, San Francisco (UCSF), graduate student [Valentina Garcia](#) is one of the first users of Gilson’s internet-connected pipettes, which she borrows from the local company representative. The pipettes send data about liquid quantities and number of pipetting steps to a tablet via Bluetooth that can then be shared with an ELN. Garcia says she plans to use the connected pipetting system in her studies of the malaria parasite *Plasmodium falciparum*, where making a mistake setting up an experiment could set her back three days or more. The system is “really great for high-throughput assays, when you’re just going to be doing the same thing over and over again, and you want to make sure you’re not getting lost in the pipetting.”

## The cloud menagerie

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It’s not just humans seeing the changes brought about by a connected lab. Moving animal research to the cloud has fostered the rise of international collaborations, given small companies the option of pursuing costly and time-consuming work in rodents, and minimized stress on lab organisms.

Veterinarian [Steven Niemi](#), director of the Office of Animal Resources at Harvard University, has investigated the effect of bringing tools for animal research and the IoT together and found reasons to pursue the integration, especially where international collaborations are concerned.

If you can share animal data directly, collaborators don't have to repeat experiments or use other animals for the same purpose, he says. "My hope is that some of this new technology can enhance" animal research, Niemi adds.

Ethan Perlstein, CEO and founder of biotech Perlara, has seen this enhancement firsthand. His company uses model organisms to study rare genetic diseases and then seeks drugs to treat those diseases. Perlara houses most of its model organisms—yeast, human cells, worms, fruit flies, and zebrafish—in labs at its headquarters in San Francisco. But working with mice presented the challenge and expense of building a vivarium, an undertaking that Perlstein says didn't make sense for the small company.

California-based Vium houses a cloud-connected vivarium and contracts with labs to do preclinical studies of drug candidates in rodents. Perlara used Vium's services to test potential therapeutics for Niemann-Pick Type C, a lysosomal storage disorder, and the project grew into a collaboration with pharmaceutical giant Novartis.

Vium's goal is to accelerate drug development while fundamentally changing the way animal research is done, says Joe Betts-Lacroix, the company's cofounder and chief technical officer. To that end, the firm's animal housing monitors temperature (which provides information about in-cage animal activity), controls airflow and lighting, and employs high-definition video cameras so sensitive that computer vision algorithms can detect the movement of an animal's chest walls and determine its breathing rate. Each cage has one or more computers that transmit data from sensors straight to the cloud, where animal care staff and researcher clients can access and analyze them online.

Not only does the setup constantly collect data from every animal, it does so without forcing the rodents to interact with people—an added benefit from a research perspective. "Mice perceive humans as deadly predators, and by the time there is a human hand reaching into the cage . . . the animals are already freaking out," Betts-Lacroix says. Minimizing these interactions could thus help researchers separate the effects of handling the animals from experimental treatment variables.

"Right now there are [approximately] eight million analog cages out there, and it's our mission to digitize them all so that we can derive the maximum amount of information from each animal," says Betts-Lacroix. "In that sense it's an animal welfare contribution because we can use fewer animals and get the same amount of information."

## Connectivity problems

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The promise of the IoT comes with both long- and short-term issues that scientists must consider. Leonelli explains that one pressing question is how far labs should go toward automation and standardization, as a one-size-fits-all approach risks overlooking nuances in data gathering or experimental design particular to a certain discipline. "Very often it is the case that people in different parts of biology have very good reasons to do things in a specific

way, which is not the same as somebody who is in a different subfield,” she says. “So one has to be very careful to capture this kind of system-specific knowledge when implementing these higher-level technological solutions.”

The IoT’s sustainability and security, particularly when it comes to data storage, are also important considerations. Leonelli says that most people and companies that are storing vast amounts of data gathered from instruments and sensors do so in clouds provided by either Google or Amazon. “What does it mean when Google and Amazon end up [with access to] most of the research data that has been produced in the public sector?” she asks. “That’s a very big question that has really not been resolved.”

Niemi highlights related concerns about data privacy, particularly when integrating the IoT into animal research—a perennially controversial area. “As your data become even more shared or more distributed, could you be compromised or could you be compromising your own program through this kind of connectivity?” Niemi asks. Among researchers working on animals, “there’s just as strong a cultural resistance to openness and sharing, even if the technology was rock solid secure,” he adds.

There are also more-practical considerations for scientists hoping to reap the benefits of introducing the IoT to their labs, not least its associated costs. For instance, although chemist Barnes found increased connectivity useful during his postdoc, he has not yet brought the IoT into his own lab at Washington University. While he is not opposed to it, connecting the lab to the cloud is not an expense that he wants to prioritize over buying chemicals or equipment, Barnes says (see table below).

And then there’s the need for scientists to get used to the protocol changes. UCSF student Garcia currently faces the practical challenge of figuring out how to integrate the new digital tool with her years of training in analog methods, such as using a paper lab notebook to track her research. “Even if I have the tablet there, if something goes wrong, I’m still writing in a notebook what happened,” she says.

All the same, to many researchers the prospect of bringing their labs online, and connecting equipment and ideas, is attractive. “The technology’s new, so it’s going to be the most buggy and the hardest to work with at this moment,” Garcia says. “But I bet ten, fifteen years from now, if I’m running my own lab, it’s going to be entirely different. It’s going to be a lot faster, a lot easier, and I think people are just going to be able to keep track of what they’re doing so much better.”

Company	Product or Service	Approximate Retail Cost
Consolidated Sterilizer Systems	Retrofitting an existing autoclave for network connectivity	\$2,000

Elemental Machines	Subscription for monitoring one connected device via Elemental Insights, a web-based dashboard	Starts at \$249/device/year
Gilson, Inc.	PIPETMAN M Connected: Bluetooth-enabled pipette that accumulates data on pipetting volumes and protocol steps with TRACKMAN Connected	\$750 to \$1,500, depending on whether single- or multichannel
Gilson, Inc.	TRACKMAN Connected: Kit including a tablet with a pre-installed microplate tracker app, PipettePilot, to complement the PIPETMAN M Connected	\$1,400
TetraScience, Inc.	Subscription for monitoring one connected device through TetraScience's web-based dashboard	Starts at \$50/device/month

GOING DIGITAL: Several companies offer cloud-enabled lab equipment and services to help bring labs online. Above is a selection of products and services currently on the market.

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