Automation: robots in the vivarium

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Automation technologies are improving efficiency in the vivarium and helping institutions keep up with the growing number of mutant rodents in their colonies.

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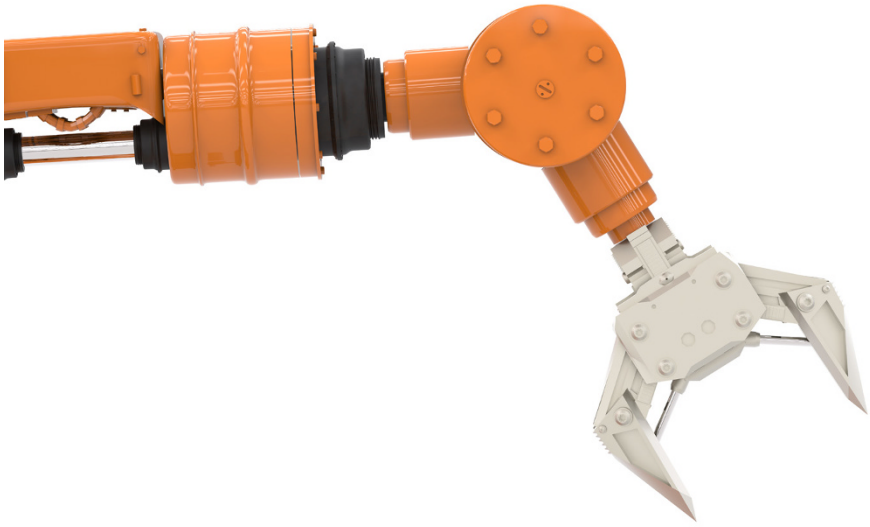

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Robotic automation is changing how institutions manage their rodent colonies.

New genetic engineering techniques, such as CRISPR/Cas9, now allow scientists to generate mutant rodents in a fraction of the time previously required, helping to drive forward large-scale projects like the Knockout Mouse Project (KOMP) that seeks to understand the functional role of every mouse gene, including many with human homologs. As the number of genetically altered mice—and rats—maintained at research institutions continues to grow[1], the burden and expense of caring for these animals have some institutions turning to automation of routine tasks in the vivarium.

Streamlining the nitty-gritty

At the Center for Comparative Medicine and Surgery at the Mount Sinai Icahn School of Medicine in New York, a yellow robotic arm that looks like it came straight out of a car factory picks up four dirty rodent cages, dumps the bedding out of them, and with a swish, places them against four automatic scrapers that remove the remaining grime. In the room next door, another robot picks up the cages and places them on a conveyor belt, which takes them into an automatic tunnel washer. Within an hour, 240 cages are cleaned.

Giving robots more of the rote responsibilities typically handled by people promises to save time and money—and to free up workers to focus on tasks more closely related to furthering research. That said, installing robotic cage washers requires significant planning, not to mention cooperation between lab managers, workers and sometimes even labor leaders.

Many moving parts

One day over the summer, a problem cropped up at Mt. Sinai: The grid that funnels dirty bedding to a vacuum system linked to the facility's dumpsters was getting clogged with nesting material. Sending the dirty bedding directly into the dumpsters is saving Mount Sinai $8,000–12,000 a year worth of garbage bags, says Gorky Estrella, Assistant Operations Manager, and Kaware Richardson, Assistant Director of Operations. They had a relatively quick fix to this problem: having staff remove the nesting material before placing dirty cages into the automated system. To gain maximum efficiency for the waste removal process, Estrella also recommends having an additional backup dumpster ready on hand. "We have a backup that we keep in stock so that when the waste removal company comes to remove our full dumpster, they can just swap it out with our backup and it doesn't disrupt our automated system."

On the opposite end of the system, where clean cages are prepared, Estrella and Richardson ran into another problem; the automatic bedding dispenser would run low and cause the system to stall. Because the automatic bedding dispenser and robotic arm were made by different companies, the two components weren't communicating with each other. This was not a problem Estrella had anticipated when his team included the robotic system into the vivarium, which was built in 2012. "Every half hour or so the bedding dispenser would empty and the whole system would shut down." To solve this problem, according to Richardson, "the best practice is to have one system made by the same company so you don't have integration problems."

Robotic cage washers such as the system used at Mount Sinai have been available for the last 15 years, but challenges in installing and maintaining the systems have slowed down their adoption; not to mention the significant upfront price-tags. Robots such as Mount Sinai's, which were provided by Tecniplast, cost about $600,000 a piece, Estrella says. But fully automated washing systems, which include tunnel washers and waste disposal and bedding dispensing systems, can cost as much as $1.5 million, estimates Brian Anderson, Business Development Director, Life Sciences at Getinge, another major provider of robotic

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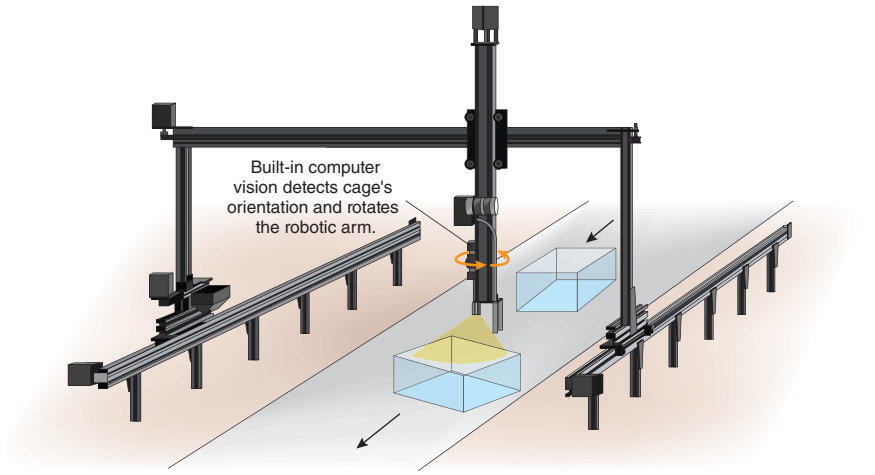
cage washers. Most lab managers agree, however, that replacing manual washing with robots offers significant benefits, not the least of which is that it cuts down on repetitive motion injuries and allergy-related illnesses frequently suffered by workers during handwashing processes. Likewise, workers free from cage washing can perform other duties to enhance the overall welfare of animals at a facility. This improves not only animal wellbeing, but also the overall quality and reproducibility of the science for which they are used.

Robotic cage washing systems have upfront price tags, but can provide long-term savings and improvements, says Brian Anderson.

Only recently has the industry started to figure out best practices for operating the robots as efficiently as possible—advances that are now making it possible for research facilities to reap significant returns on their investments. "The biggest benefit of automation is improving quality and precision," says John Hasenau, principal consultant at Laboratory Animal Consultants in Reno, NV. "Robotics for cage washing has seen a big push in the last five years in terms of innovation." Once vivarium staff members grow comfortable with robotic cage washing systems, institutions can add complementary technologies to boost efficiency even more. At Harvard University's Cambridge, MA, campus, for example, they've added RFID tags to each cage and antennas in the ceilings to read those tags. That allows them to count cages automatically and keep track of which room each cage is in, without staff having to scan the tags using handheld devices. "We now have a digital record of every cage, and we've reduced the administrative time it takes to process a monthly inventory of all of our cages from 10 hours to 30 minutes," says Steven Niemi, director of the Office of Animal Resources at Harvard. Niemi also highlights how more automation can help staff and investigators work together better. "In addition, the digital cage ID platform now allows us to customize cage components easily if an investigator wants a different bedding, food, or nesting material." The potential for such efficiency gains will continue to drive the adoption of robotics, predicts Brian Wu, an engineer at Mount Sinai who helps with the upkeep of its robotic cage washers.



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Gantry-style robotic systems provide on-the-fly adjustments to minimize disruptions during cage processing.

Twists and turns

There are two main types of robotic systems that can be employed for cage washing. The first is the traditional swinging-arm system. The other is what's known as a gantry system, which runs on rails and incorporates cameras and computerized vision, offering some degree of flexibility that's not available with swinging robotic arms.

Gantry-style robotic systems can provide increased flexibility for automatic cage washing, says Edward Jaskolski.

The University of Massachusetts Medical School has experience with both types of systems but has found significant benefits with the gantry-style robot it installed three years ago. "With traditional robots, the cages come through a special washer where the cages have to be in an exact location," says Edward Jaskolski, associate director of animal care at the university. "The biggest benefit we saw with the gantry system is that it operates off a camera, allowing the robot to go to each cage and pick it up, even if it's crooked or not in the correct location."

Planning ahead

Although robotic systems can be customized to fit existing spaces, most of the recent adopters of robotic cage-washing systems, including Mount Sinai, are building the technology into new laboratories rather than retrofitting existing facilities to accommodate it. When designing a facility that will include robotic cleaners, space requirements need to be planned out in advance, since each robot needs its own room that's at least 10 feet high and 10 feet long, plus additional space for tunnel washers and other equipment, estimates Marco Pagani, area manager for washing and automation solutions at Tecniplast.

There are also logistical challenges that are easier to work out when a robotic system is being planned from the get-go. Robots that handle dirty cages must be separated from the clean part of the process, with room left for lab workers to stack cages and transport them from one piece of equipment to the next. "We needed a long, linear space for all the components," says Clifford Roberts, associate vice chancellor of research at the University of California at San Francisco (UCSF), which built two robots and two tunnel washers into a new animal facility that it began planning in 2000.

Even though that planning process allowed UCSF to substitute five workers with two robotic cage washing systems, the efficiency gains didn't come from having fewer people on the cage-wash task, Roberts

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says. On the contrary, people can actually clean cages faster than robots can, he says. But robots offer some key advantages. "You have to measure practical efficiencies," he says. "Our two robots can handle 450 to 500 cages an hour, and they can work through lunch hours and coffee breaks. People have problems with allergies, injuries, the usual slips and falls—those happen when they try to work at their peak all day long. That's really difficult to sustain."

Teamwork

In fact, robots aren't replacing lab workers, but rather making it possible for staff to be repurposed in ways that some lab managers believe enhances both animal welfare and employee morale. When Yale University started planning for its robotic cage-washing system in 2009, the labor union that its cage washers belonged to raised concerns about job security, says Eric Georgelos, director of operations at the university's animal resources center. The automation made two cage-washing positions obsolete, so after two employees retired, the university filled those positions to work in a newly established gnotobiotics core facility.

Having staff trained to help with the upkeep of robotic systems saves time and money for facilities, says Christopher Southern.

"At first there was a lot of skepticism among union leaders," Georgelos says. "It took time for them to see that we could re-task our headcounts." Because automation is still not widely used in animal research, Georgelos advises lab managers to be open and honest with labor leaders, and to include them in the planning for new automated systems. "Talking about this early with union representatives was really important," he says. "It laid the groundwork. They could see we would be able to use displaced workers to grow our capabilities."

One of the biggest challenges lab managers face with robotic cage-washing systems is being able to get them back up and running quickly if they malfunction. Training staff to properly maintain the robots can have big benefits for the institution, and the worker. After Baylor College of Medicine installed two Tecniplast robots in a new lab in 2006, for example, it took one of the employees who had been manually washing cages and had him work with the company to learn how to maintain the equipment. The company came out and did a lot of one-on-one training and it was a win-win for the university and the employee, says Christopher Southern, Operations Manager at Baylor College of Medicine, Center for Comparative Medicine. "It was a big career opportunity for him," Southern says.

Worthwhile growing pains

Embracing automation is rarely a smooth process, and some vivarium managers have found that installing robotic systems requires that they make other changes as well. For instance, ensuring that the cages a university has previously invested in fit well with the new robotic system is crucial, and can add additional costs to getting things up and running.

But after various obstacles are overcome, the benefits of robotic cage washing can become clear. "It is efficient, because the person running the tunnel washer can get the cages loaded and walk away," says Carrie Freed, a clinical veterinarian at Ohio State University. "It allows us to stay on top of the cleaning process. And I absolutely believe that being able to have clean, sterilized supplies available for any needed cage changes on the spot plays into animal welfare."

There are even more innovations in automation coming down the pipeline. Some companies have developed automated aquarium washers for research facilities that house zebrafish, for example, Hasenau says. Others are incorporating video capabilities and electro-magnetic field technology into rodent cages to improve the ability of vivarium managers to monitor sanitation levels and to analyze the comfort level of the animals. Tecniplast is working on embedding sensors into cage racks that can detect how dirty the bedding is, and automatically create work plans to help supervisors schedule their workloads over the coming days.

In addition to efficiency gains, automation enables staff to improve animal welfare, says Carrie Freed.

"The objective of all these systems is to decrease the variability" in factors like cage cleanliness, Hasenau says. "Our reliance on having those individuals in the room for major observations will not decrease, but technology will augment that quite a lot. It will make it much more beneficial for everyone, including the animals."

1. Smalley, E. CRISPR mouse model boom, rat model renaissance. *Nat. Biotechnol.* **34**, 893–894 (2016).

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