Kevin Dooley/Flickr

"Can you point to Center City?" neuroscientist Russell Epstein likes to ask visitors to his office at the University of Pennsylvania in Philadelphia. Sometimes they can do it. Sometimes they have a little trouble. And sometimes, Epstein says, "they have no idea how they'd even begin to solve that problem."

Epstein studies the way people navigate through space and orient to their surroundings–which turns out to be a very challenging problem for some people. His work builds on the research in rats that earned three scientists the Nobel Prize in Physiology or Medicine this morning. The prize-winning work identified certain types of neurons in the brain that are integral to the brain's internal navigation system.

Epstein is one of several researchers trying to connect the dots between that rodent research and individual differences in people's ability to orient to their surroundings and find their way from one place to another. As you may have noticed, all people are not equally good at this.

In a study published last year, his lab teamed up with psychologists from nearby Temple University to investigate what happens as people get to know a new place over the course of a few weeks. They took Temple students to a suburban campus they'd never seen before and showed them two short walking routes that passed by four buildings that served as landmarks. To keep the students from making a connection between the two routes, they blindfolded them and pushed them in wheelchairs from one to the other.

In subsequent visits, the researchers showed the students two different paths that connected the two routes they'd learned. Then they did some tests to try to see which students had put all the pieces together into a mental map of the new campus. For example, they'd ask a student to imagine standing in front of one of the eight buildings and point to the other seven. "Some people could do it well, and other people couldn't do it all that well," Epstein said. "That's not terribly surprising." What he and his colleagues really want to know is what's going on in the students' brains that might account for that difference.

When they did MRI scans of the brains of 13 of the students, they found a correlation between the size of the right hippocampus—a region with important roles in memory and navigation, and the focus of the Nobel-winning research—and how well a person had done on the imaginary pointing task. That suggests to Epstein that people with a bigger right hippocampus, and even more specifically, the posterior or back end of the right hippocampus, may be better able to get oriented to new places.

It's just one study, and a fairly small one at that, but the findings fit with other research. The most famous of these are the cab driver studies by Eleanor Maguire and her colleagues at University College London. Since the early 2000s, Maguire and her team have studied London cabbies as they learn The Knowledge, the navigational wherewithal to get a passenger from point A to B through the city's medieval maze of streets without looking at a map or using GPS as a crutch.

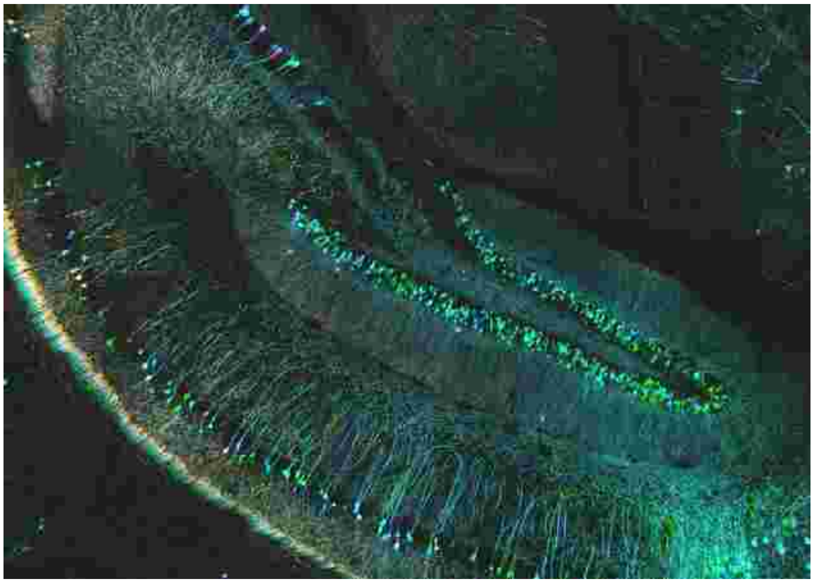
London streets. *Map: OpenStreetMap contributors*

A few years ago, Maguire's team scanned the brains of 79 cabbie wannabes just about to embark on the three to four year training program, and they scanned most of them again afterwards (only 39 had managed to pass the qualifying exam—London is confusing!). MRI scans showed that the posterior hippocampus had gotten slightly larger in those who'd successfully crammed The Knowledge into their heads. Those who flunked out showed no change, the researchers reported in *Current Biology*.

Epstein says those findings show pretty convincingly that intensive geographical training can increase the volume of the posterior hippocampus. It's the same area Epstein's campus navigation study implicated, but in that case he suspects the students' performance was impacted by pre-existing differences in their brains. "People came in with these differences [in the size of their posterior hippocampus] and that affected how well they learned the campus," he said.

But what does this little chunk of the brain actually do?

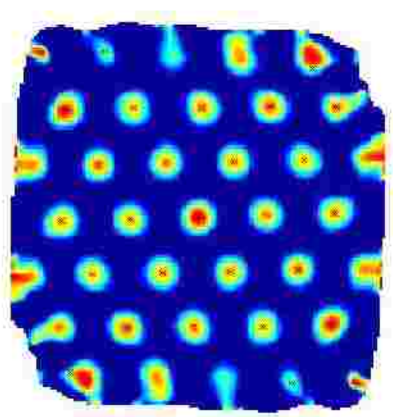
Important clues have come from work honored by today's Nobel. Half of the prize went to John O'Keefe, a neuroscientist at University College London, for the discovery of "place cells." In the early 1970s, O'Keefe used hair-thin electrodes to record the electrical activity of neurons in the hippocampus of rats as they ran around an enclosure. Place cells, as their name suggests, fire only when the rat passes through a particular place. The other half of the Nobel went to May-Britt and Edvard Moser, neuroscientists at the Norwegian University of Science and Technology in Trondheim for the more recent discovery of "grid cells" in 2005. These cells fire at regular intervals as a rat moves through space, marking out an imaginary grid.



The mouse hippocampus. *Image: ZEISS Microscopy/Flickr*

Put those cell types together and you've got something a rat could actually use to get around. The grid and place cells form a kind of map: The grid cells mark out a reference grid, roughly analogous to latitude and longitude lines (the *graticule*, if you want to get technical about it), and the place cells are like pins indicating specific places. A third type of hippocampal neuron, the so-called "head direction cells," act like an internal compass, with certain ones firing depending on which way the rat is pointing its nose."

In the rat equivalent of the posterior hippocampus, the place cells are finely tuned—they only fire when the rat passes through a specific spot. Perhaps people who remember locations better and don't get lost as much have more of those finely tuned cells packed into a larger than average posterior hippocampus, Epstein says. He admits that's speculative, however.



Grid cells tend to fire at fixed points on a triangular grid. *Image: Torkel Hafting/WikiCommons*

Scientists don't really know if all of the rat findings apply to humans as well, but recent studies suggest that humans do at least have place and grid cells, and probably head direction cells too. A few clever experiments have turned up evidence of these cells by having people explore virtual reality environments inside an fMRI scanner. Even more direct and compelling evidence comes from monitoring electrodes inserted into the hippocampi of human epilepsy patients prior to surgery.

The hippocampus isn't the only part of the brain important for navigation though. Several studies suggest which other brain regions may contribute: Taking note of landmarks seems to be the job of the parahippocampal place area; triangulating the position of different landmarks in relation to each other may be the responsibility of the retrosplenial cortex; and storing cognitive maps of the places we've been is probably the job of the medial temporal lobe, which includes the hippocampus and its neighbors.

Epstein suspects we have different types of mental maps filed away in our brains. We might have highly detailed maps of important places like our homes and offices, he hypothesizes, but only looser representations of the spaces in between. Or, zooming out a bit: "I might have good map of Philly and a good map of New York City, but it's not like I have a complete map of New Jersey," he said.

How the brain stores those different maps and calls them up when we need them is the sort of thing Epstein wants to understand. He and his colleagues are still a long way from a complete account of how the human brain navigates and what makes some people's brains better at it than others. But they're beginning to put a few points on the map.

Tags: Brains and Behavior, navigation, nobel prize