Like air traffic, information flows through neuron 'hubs' in the brain

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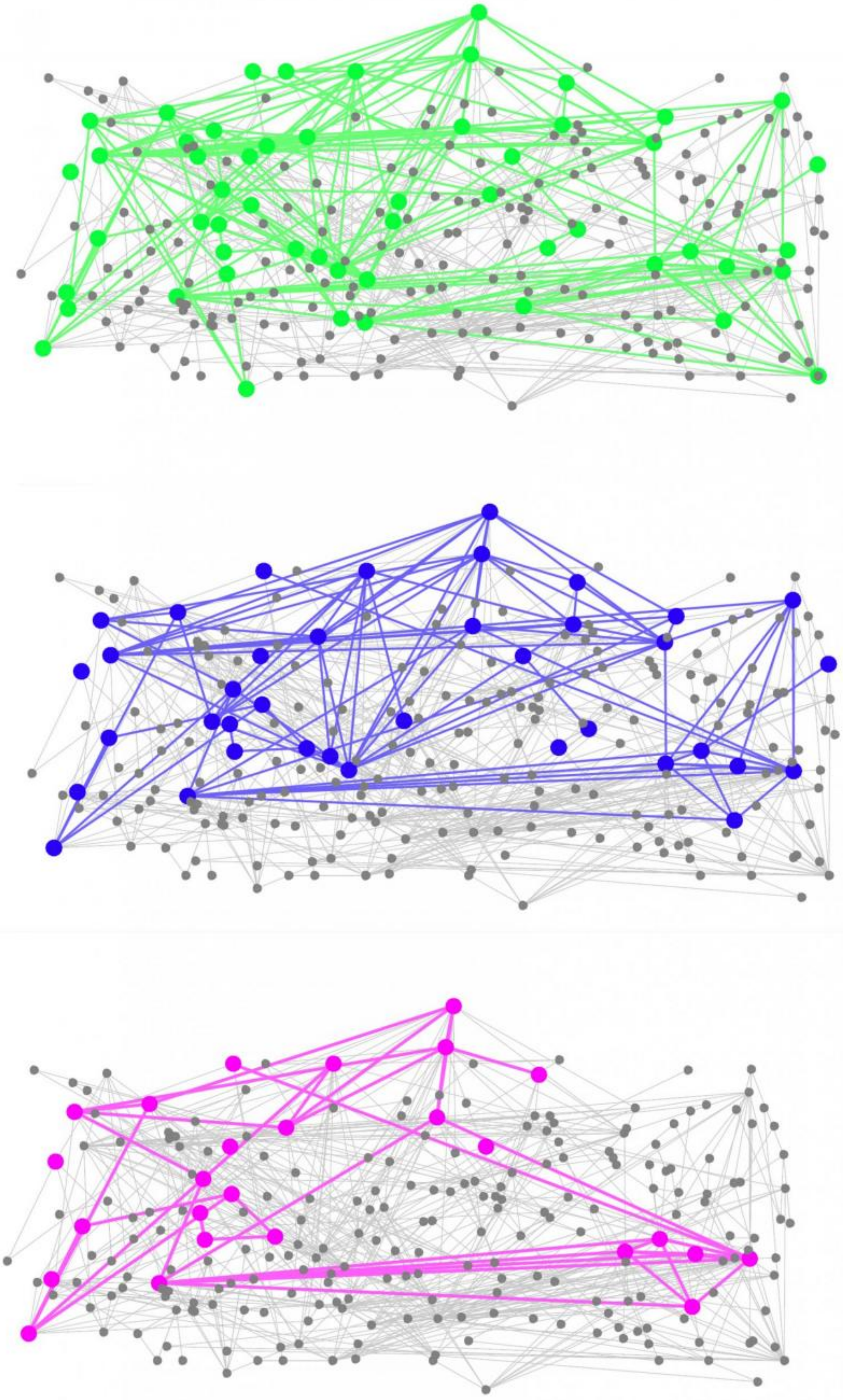

Non-gray circles and their connections represent 80, 70 and 60 percent (from top to bottom) of all outgoing traffic within the sampled section of a cortical region. Credit: Indiana University

Just as most of the world's air travel passes through a few major hubs, the majority of information in the brain flows through similarly well-traveled routes, Indiana University scientists have found.

A new study, reported Jan. 19, 2016 in the journal *Neuroscience*, shows that 70 percent of all information within cortical regions in the brain passes through only 20 percent of these regions' neurons.

"The discovery of this small but information-rich subset of neurons within cortical regions suggests this sub-network might play a vital role in communication, learning and memory," said Sunny Nigam, a Ph.D. candidate in the IU Bloomington College of Arts and Sciences' Department of Physics, who is the lead author on the study.

The scientists also report these high-traffic "hub neurons" could play a role in understanding brain health since this sort of highly efficient network—in which a small number of neurons are more essential to brain function—is also more vulnerable to disruption. That's because relatively small breakages can cause the whole system to "go down."

"The brain seems to favor efficiency over vulnerability," said John M. Beggs, associate professor of biophysics in the IU Bloomington Department of Physics, who is senior author on the paper. "In addition to helping us understand how the cortex processes information, this work could shed light on how the brain responds to neurodegenerative diseases that affect the 'network.'"

If the higher metabolic rates of hub neurons make them more vulnerable, for example, the resulting damage could be particularly harmful in conditions in which neurons are known to die, such as Alzheimer's disease.

The existence of neurons that carry the majority of information between cortical regions in the brain has been previously reported by Olaf Sporns, Distinguished Professor and Robert H. Shaffer Chair in the IU Bloomington Department of Psychological and Brain Sciences, who is a co-author on the paper. But the new study is the first to show that a similar dynamic exists in communication within cortical regions, or the "micro-structures," of the brain.

It is also the first to measure activity across a particularly large number of neurons in these regions.

To conduct the study, IU scientists recorded small electrical impulses from up to 500 neurons from the somatosensory cortex—the part of the brain responsible for the sense of touch—measuring a surprisingly large volume of traffic across a relatively small area.

As a collaboration across the fields of physics, informatics, neuroscience, and psychological and brain sciences, the IU scientists were able to reveal the flow of both outgoing and incoming information within the living neural network by combining data from extremely high-resolution imaging technology with complex biophysical computer simulations of the brain.

"This is the first study to combine such a large number of neurons with such high temporal resolution," Nigam said. "As a result, we can actually detect the direction of the communication flowing between neurons, creating a 'transportation map' from the connections within the cortex."

The experiments, conducted in live and tissue samples, were based in rodents. But similar high-traffic zones in the cortex have been shown to exist in more advanced mammals, including primates and adult humans. The IU study is the first to explore the behavior of this region in mammals at the level of individual neurons, however, with the only previous similar experiment conducted in worms.

Nigam added that understanding how the brain maintains good "air traffic control" between information-rich and information-poor neurons will be the next step in unraveling the mystery of hub neurons.

"If we ever want to understand how these types of neurons keep information in our heads flowing smoothly," he said, "we really need to learn a lot more about how they work together."

Provided by Indiana University