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RESEARCH NEWS

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Exercise Improves Learning and Memory

Chalk up another benefit for regular exercise. Investigators from the Howard Hughes Medical Institute (HHMI) have found that voluntary running boosts the growth of new nerve cells and improves learning and memory in adult mice.

"Until recently it was thought that the growth of new neurons, or neurogenesis, did not occur in the adult mammalian brain," said Terrence Sejnowski, an HHMI investigator at The Salk Institute for Biological Studies. "But we now have evidence for it, and it appears that exercise helps this happen."

> "These observations support the idea that exercise enhances the formation and survival of new nerve cells as well as the connections between nerve cells, which in turn improves long-term memory."
> **— Terrence J. Sejnowski**

Sejnowski, Salk colleague Fred Gage, and postdoctoral fellows Henriette van Praag and Brian Christie, published their findings in the November 9, 1999, issue of *Proceedings of the National Academy of Sciences* .

The investigators began their study by comparing the memory skills of a group of sedentary mice to those of a group of mice who exercised freely on a running wheel for one month. Mice in the exercise group logged an average daily distance of 4.87 kilometers, or 2.92 miles.

Both groups were trained to locate a submerged camouflaged platform in a maze that was lying just below the surface in cloudy water. Mice dislike swimming and instinctively seek the platform as a refuge from the stressful activity.

"We can't ask a mouse if it remembered where the platform was located, so we measure long-term memory by having them swim to the platform," said Sejnowski.

After six days of training each group of mice for the swimming task, the researchers began the study. The group of mice that had been exercising made a beeline for the platform. In contrast, the sedentary mice took significantly longer paths and times to find the dock. The path chosen and time taken reflect long-term memory, or how well the mice recall the platform's location. Based on the swimming test, mice in the exercise group were better able to remember the platform's location compared to mice in the sedentary group.

Next the researchers looked for changes in the number of nerve cells between the two groups of animals. In comparison to sedentary mice, the brains of mice that exercised had about 2.5 times more new nerve cells.

New nerve cells were not distributed evenly throughout the brain, but were concentrated in the dentate gyrus, a section of a larger area of the brain called the hippocampus. The hippocampus plays a central role in many memory formation processes, including spatial learninglocating objects in the environmentand consciously recalling facts, episodes, and unique events.

The investigators also examined brain slices from the two groups of mice in order to measure a nerve-signaling process known as long-term potentiation, or LTP. A large body of research supports the theory that LTPessentially a strengthening of the synaptic connections between two neuronsis the primary mechanism involved in the formation and storage of long-term memories by humans and animals.

"Presumably, LTP affects the flow of information through synapses, the connections between two nerve cells," said Sejnowski. Neurons communicate with each other by sending signals through synapses.

Examination of the tissue slices showed that the exercising mice displayed twice as much long-term potentiation compared to their sedentary counterparts. And, as was the case with neurogenesis, increased LTP occurred only in the dentate gyrus.

"These observations support the idea that exercise enhances the formation and survival of new nerve cells as well as the connections between nerve cells, which in turn improves long-term memory," Sejnowski explained. He added that these data also confirm that the structural and physiological changes that occurred in the dentate gyrus correlate with a learning behavior associated with this region of the brain.

Numerous human studies have shown that exercise increases alertness and helps people to think more clearly. Recently, Gage demonstrated that new nerve cells grow in the adult human dentate gyrus. If the same correlation between exercise, nerve cell growth and memory observed in mice plays out in the humans, "exercise could help you remember the name of the person you met yesterday to or where you parked your car," said Sejnowski.

In future experiments, Sejnowski and his colleagues will follow individual mice to see whether longer running times generate more new nerve cells and stronger long-term potentiation. They will also explore if other factors, such as hormones released by exercise, influence memory and nerve cell growth. "We still don't have the causal link between exercise and neurogenesis," said Sejnowski.