Neurolab opens new pathways for studying the life sciences

by Marsha Freeman

The April 17 launch of the Space Shuttle Columbia, carrying the Neurolab laboratory, is the third Space Shuttle mission dedicated to studying the impact of microgravity on living systems. The flight is scheduled for 16 days, to provide the maximum time in space that the Shuttle allows, for each of the 26 Neurolab experiments on board. If there is an adequate supply of consumables, NASA will give the go-ahead for a 17th day in orbit. Every experiment on Neurolab will provide valuable insights that will further the understanding of the development and functioning of the brain and nervous system.

The previous life sciences Space Shuttle missions included experiments to investigate a broad range of effects produced by the unique environment of space. This mission will focus specifically on the nervous system, including the brain, the spinal cord, nerves, and the sensory organs. The idea for the mission originated in 1991, after it had been declared that the 1990s would be the "Decade of the Brain."

It has been known for many years that when astronauts enter Earth orbit and weightlessness, there is a process of adaptation. Some of the adaptation symptoms are an inconvenience, such as the redistribution of bodily fluid, which pools in the lower extremities on Earth but evens out in space, producing a bloated and stuffy feeling in the head. Some adaptation effects are at least partially disabling, such as queasiness and spatial disorientation, which can interfere with normal activity.

NASA has long sought to uncover the causes of space adaptation syndrome, with the goal of developing prophylactic measures to eliminate the discomfort for space travellers. And, there are other aspects of the adaptation of the body to space that are not a problem in orbit, but manifest when the astronaut returns to the gravity of Earth.

These include bone decalcification, immune system diminution, orthostatic intolerance (the inability to stand up without feeling faint or dizzy), and vestibular (balance and position) disturbances. Understanding these changes could lead to mitigating their effects, shortening the period of readaptation to Earth's gravity that astronauts now undergo. For future missions, scientists must understand the physiolgical impact of partial Earth gravities that are encountered on the Moon and Mars.

Previous experiments indicate that there may be physiological changes in the brain and nervous system of an adult under the influence of microgravity. There may well also be fundamental, and perhaps irreversible, changes in the nervous systems in neonates placed in weightlessness, which could have profound implications for future generations born on the Moon or Mars.

Because many of the symptoms suffered by healthy space travellers mimic the symptoms suffered by the elderly in the course of the aging process, or by the infirm due to disease, the National Institutes of Health was a partner with the space agency for this Neurolab mission, to participate in experiments, as were eight nations in addition to the United States.

Man in space

The nervous system controls blood pressure, maintains balance, coordinates body movements, and regulates sleep. All these are areas that are affected by space flight. There are four Neurolab teams that will use crew members as subjects in 11 experiments, in order to study the autonomic nervous system, sensory motor performance, vestibular functions, and sleep.

The autonomic nervous system controls involuntary functions, such as heartbeat, respiration, and blood pressure. The orthostatic intolerance suffered by about 60% of astronauts after a mission, and many elderly persons, is the result of a lack of blood flow to the brain. In Neurolab, the crew will carry out a set of tests to measure blood pressure, and also blood flow to the brain, to determine how they are affected by microgravity. High-frequency sound waves will be used to show how blood flow to the brain is regulated, and a small needle placed just below the knee will measure the nerve signals travelling from the brain to the blood vessels, to indicate how the autonomic nervous system is functioning.

A number of experiments on Neurolab will examine the adaptation of sensory motor functioning. On Earth, when you catch a ball, the brain receives information from the eyes, inner ear, and nerves in the joints and muscles to coordinate your movement. In doing so, it takes the effect of Earth's gravity into account.

We know that the central nervous system does adapt to weightlessness, but on Neurolab, for the first time, precise measurements will be made to assess how the brain accepts and interprets a new set of stimuli. Experiments will include throwing a ball, while monitoring the electrical activity in the

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arm muscles. Various other visual-motor coordination tests will be performed.

Our inner ears, structures which depend on gravity on Earth in order to function, go through a period of adaptation in space, and a readaptation upon return to Earth. The balance organs in the ear work in tandem with the eyes, brain, and muscles, to direct our movements. After a long stay in space, astronauts experience vestibular disturbances, such as feeling unsteady on their feet, and often walking down stairs and turning corners with difficulty.

A variety of experiments will be carried out in Neurolab to provide scientists with an understanding of how the brain reinterprets vestibular data in space. Crew members will make use of equipment that will test their ability to sense movement, such as rotation, correlated with eye movements, which are an important measure on Earth of inner-ear vestibular function.

One problem a majority of astronauts share with a large percentage of the elderly is sleep disturbance. While this can be due to a number of causes on orbit, palliatives are definitely necessary. For the first time, crew members will be administered the hormone melatonin, to see if this improves their quality and quantity of sleep. In addition, a new portable system for recording sleep and respiration during space flight has been developed, and will be used on Neurolab.

Animals to help

Many experiments on the most interesting and important questions about the effects of microgravity on the brain and nervous system cannot be answered through experimentation with human subjects. In those cases, scientists try to find high-fidelity, non-human analogues to study. Aboard Neurolab are over 2,000 animals and fish.

It has been observed on previous Shuttle missions that some young animals in space fail to develop critical capabilities that they do not need there, but that they do need back on Earth. Scientists hope to be able to identify such "critical periods" in the development of motor and other skills in animals, determine if there are neurological differences with Earth-raised control animals, and if the deficit is reversible.

One team of researchers is using rats and mice at various stages of development to study mammalian development, including how muscles and the nervous system change in the absence of gravity. Brain tissue from young rats who "grow up" on Neurolab will be examined after the mission to see how microgravity affects the structure and funtion of the hippocampus area of the brain, which is involved in spatial ability.

Another experiment will investigate the development of the vestibular system which is not exposed to Earth-gravity stimuli in space, and neuromuscular development in young rats will also be observed. Brain development will also be studied through focussing on the cerebral cortex of mice embryos. Pregnant animals will have cell markers administered to their embryos to label the nerve cells at their "birth," and follow them as they migrate through the developing brain.

Since people are able to function well in space after a relatively short period of adaptation, the nervous system clearly can adapt to the extraordinary conditions of a lack of gravity, adjusting blood pressure, and learning to allow an astronaut to locomote and sleep. This is accomplished through a phenomenon known as neuronal plasticity, in which neurons react to changed conditions by making new connections, or by using existing conditions differently, as it is described. Using rats as subjects, researchers will explore how this learning occurs in space. In one experiment, scientists will study the structural and chemical changes that occur in the cerebellum of the brain, to see how the plasticity of the brain helps maintain balance and equilibrium.

Astronauts on Earth orbit experience a sunrise every 90 minutes, disrupting their circadian rhythms. Similar disruptions are suffered on Earth among the elderly and shift workers, and in jet lag, insomnia, and winter depression. On Neurolab, rats will be exposed to different light cycles to determine how the neurons in the brain that control body temperature, heart rate, and activity, are affected.

Snails and fish are being called into service on Neurolab, to help researchers investigate physiological changes to the vestibular system in the absence of gravity. Gravity-sensing systems in snails and fish are similar to, but simpler than, those in humans.

Oyster Toadfish will be studied to determine how their otolith organs that sense motion, similar to those in the human inner ear, experience neuronal plasticity to allow them to sense gravity and body position in the free-floating environment of space. Electrodes will be placed in small cuts in the nerve cells that connect the inner ear with the brain of the toadfish, to study changes in the "nerve traffic" between the otolith and brain. Freshwater snails and swordtail fish at various stages of development will be used to study how microgravity affects the *formation* of vestibular organs.

And finally, the crickets on board the Shuttle are good candidates to provide insight into nervous system changes in space, because their gravity sensors are connected to a simple nervous system, that has been well studied. Crickets at several early developmental stages (eggs and larvae) are in Neurolab. Some crickets will be placed in a rotating compartment that simulates Earth's gravity, and others will experience microgravity conditions. The investigator anticipates that during a critical period of early life, microgravity will interfere with the normal development of the crickets' gravity-sensing system.

After flight, researchers will be able to measure the consequences on development in space by observing the crickets, because these insects are known to roll their heads when tilted, which is a reflex that is activated by its gravity-sensing system. The researchers also anticipate that the crickets will be able to regenerate their gravity-sensing systems once back on Earth.