# Bacteria alive and thriving at depth

In recent years, scientists have found bacteria, as far down as 1,150 feet, in wells that penetrate deeply buried aquifers — porous layers of rock that hold underground water. Such finds have forced hydrologists to question their traditional belief that deep aquifers were void of life. But it was not clear whether these bacteria were native residents of the aquifers or just contaminants from the world above, living solely within the wells. Moreover, no one had established how the bacteria were affecting their environment, if at all.

Experiments are now demonstrating for the first time that bacteria are indigenous to deep aquifers and that they actively change the chemistry of the groundwater, reports a group of hydrologists and microbiologists.

"The bacteria do a lot. They are probably one of the most important processes in determining groundwater chemistry," says Francis H. Chapelle of the U.S. Geological Survey (USGS) in Columbia, S.C., who conducted the experiments along with USGS colleague Peter B. McMahon, James T. Morris of the University of South Carolina in Columbia and Joseph L. Zelibor Jr. of the University of Maryland in College Park.

In a set of experiments near Hilton Head, S.C., Chapelle and his colleagues drilled more than 100 feet down into an aquifer and pulled up sediment cores, from which they isolated bacteria that were attached to the particles of sediment. In the laboratory, the researchers incubated the bacteria and demonstrated that the organisms metabolically produced carbon dioxide under both aerobic and anaerobic conditions, according to a report in the February GEOLOGY. Groundwater typically contains dissolved carbon dioxide gas.

The scientists could relate this laboratory-produced gas, by means of a peculiar isotopic signature, to that found dissolved in water from the aquifers. Earlier experiments had shown that the carbon in water from this particular aquifer was abnormally rich in carbon-13, a heavy isotope of carbon. Chapelle's group found that the carbon generated in the lab also contained high levels of carbon-13. He suggests that the bacteria, which feed on organic molecules, have a metabolism that selects this heavy isotope when producing carbon dioxide.

The gas can greatly affect the chemistry of the groundwater in the aquifer, says Chapelle. Dissolved carbon dioxide acidifies water and helps it eat away the limestone rocks of the aquifer. Such activity will enlarge the pores in the rock, enabling water to flow more freely through the aquifer and increasing the amount of water the aquifer can hold.

According to microbiologist Derek Lovley, the recent study "shows the potential for aerobic microbial metabolism to affect the geochemistry through $CO_2$ production." However, Lovley, from the USGS in Reston, Va., says production rates measured in the lab were much higher than they would be in the ground. More work is required to understand what factor is limiting the bacteria in the natural environment.

None of the bacteria studied by Chapelle is infectious, and most would not significantly affect the drinking quality of water in the deep aquifers. However, some bacteria can make water less suitable for human use. Certain species reduce iron, making the metal more soluble in water. In tap water, iron can produce stains and an unpleasant taste.

Hydrologists have detected signs of bacteria in deep aquifers in many locations, says Glenn Patterson of the USGS in Columbia. Some bacteria are known to feed on toxic chemicals, and researchers are now exploring how bacteria may aid in cleaning up chemical spills.

*— R. Monastersky*

# Neural networks set sights on visual processing in brain

The past few years have witnessed an explosion in scientific attempts to develop computer models that simulate the behavior of small groups of brain cells involved in functions such as vision and smell (SN: 1/24/87, p.60). According to a report in the Feb. 24 NATURE, one such "neural network" has demonstrated the ability to code visual information much in the way that has been observed among monkey brain cells concerned with estimating the position of visible objects. David Zipser of the University of California at San Diego and Richard A. Andersen of the Massachusetts Institute of Technology in Cambridge say that the cortex, or outer layer of the brain, and their computer model may handle incoming information similarly.

"This is one of the first applications of neural network technology to experimental data from the brain," says biophysicist Terrence J. Sejnowski of Johns Hopkins University in Baltimore, who has designed a similar computer simulation of neuron activity in the cat brain. "We can apply this type of model to different parts of the cortex as an all-purpose tool for studying brain function."

Zipser and Andersen, as well as Sejnowski, use a neural network training procedure called "back propagation." The system contains a layer of input units, a layer of output units and an intermediate or "hidden" layer of units, which, with repeated trials, takes on response properties that best accomplish the computational task being learned. As training proceeds, error signals are sent back through the network to adjust the strengths of connections between all units in order to nudge the system toward a desired output.

In this instance, the trained responses of the hidden layer were compared to electrical measurements taken from a small area of monkey cortex containing neurons that track the visual field and eye position. Lesion studies indicate that monkey neurons in this region combine information about the position of an object on the retina of the eye with information about the direction in which the eyes are pointing; this helps determine the object's location in relation to the body.

The model network was trained using randomly selected pairs of input eye positions and retinal positions. The true spatial location implied by each pair of inputs was programmed into the model and generated error signals that produced accurate spatial estimates within about 1,000 trials.

In learning to carry out this task, say the researchers, the system modified itself so that "hidden unit" responses to visual input closely matched electrical responses of critical monkey neurons when the animals view an object. This supports the notion, they add, that the brain carries out a number of steps in determining where an object is, including the combining of retinal and eye position information.

Sejnowski's neural network uses back propagation training to compute curvature from shading in an image, an important part of depth perception. Input units in the network are arranged to mimic the activity of visual receptor cells in the cat. After training, hidden units acquire properties much like those of cells in the cat's visual cortex that are sensitive to elongated shapes. In addition, output units behave like another class of neurons that further process information about shapes.

"These little networks are not models of the brain per se," says Sejnowski. "But we can develop networks that help to understand the functioning of particular circuits in the brain. Just as calculus can be applied to problems in a variety of disciplines, a back propagation network can be applied to the study of different parts of the cortex." *—B. Bower*