How nerves and muscles get together

One of the most provocative questions facing neurobiology today is how neurons decide which muscle cell to hook up with. Do they have certain recognition molecules that interact with only the right muscle cell, thus leading to synapse formation? Or do they zero in on whatever target cell is available, in an indiscriminate manner?

The latter explanation appears to be the correct one, according to research by Donald G. Puro and Nobel laureate Marshall Nirenberg of the National Heart and Lung Institute. The scientists report their findings in the October PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES.

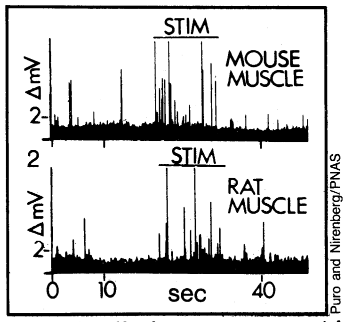
The best way to understand interactions between neurons and target cells would be to study a homogenous population of embryonic neurons as they synapse with target cells. But unfortunately, embryonic neurons, unlike other kinds of cells, are only one of a kind: they do not divide into more copies of themselves. So Nirenberg and two other researchers in his lab, Berndt Hamprecht and Takehiko Amano, using specific laboratory techniques, decided to make a population of homogenous embryonic neurons.

They made a clonal line of mouse neuroblastomas—embryonic neurons that are cancerous and therefore, unlike normal embryonic neurons, able to divide into copies of themselves. They fused neuroblastoma cells from their clone with cancerous neurons from rats in order to form an ultimate clone of hybrid neurons that secreted the neurotransmitter acetylcholine. Neither of the parent clones of neurons made this neurotransmitter. Acetylcholine is a nerve chemical that electrically stimulates muscle cells.

Puro and Nirenberg then took some of these acetylcholine-secreting hybrid neurons, called NG108-15 cells, and put them in the presence of muscle cells. The muscle cells were from three different organisms—the rat, mouse and chicken. The muscle cells were also from different kinds of muscle, for example, pectoral and hindlimb.

By electrically stimulating individual neurons and measuring the electrical response of individual muscle cells to this stimulation, the scientists were able to determine which neurons had formed synapses with which muscle cells. They found that the neurons formed synapses with some 75 percent of the muscle cells present. These included muscle cells from all three organisms and also from several kinds of muscle. The synapses did not show any obvious differences in the efficiency of electrical stimulation, nor did the muscle cells show any significant variations in response to it.

These findings suggest that neurons form synapses indiscriminately with muscle cells in their presence rather than



Hybrid cells form synapses with mouse and rat muscle respectively.

zeroing in on select ones, not others. This situation in turn suggests that neurons do not have molecules that act as receptors for hooking up with select muscle cells. Puro and Nirenberg, in fact, have some other, yet unpublished evidence to support this conclusion: Under certain conditions, muscle cells were innervated by functionally inappropriate neurons. Several other groups of investigators have found the same thing.

So what gets the right neurons "talking" with the right muscle cells if a cell molecule recognition code does not? Whether neurons communicate with neighboring cells may depend on events that take place *only* after synapses are formed, Puro and Nirenberg propose. In other words, whether a synapse works may depend on how effective the transmission of electrical and chemical signals across the synapse is, not on whether certain neurons and target cells make contact in the first place. □

Viking: Riches in a radio beam

How big is Mars? How dense is the sun's corona? How much matter fills the not-so-empty space between planets? And just where did the Viking landers really land? Such wide-ranging questions—and there are twice as many more on the list—are all part of the assignment for the least-known of the Viking project's 13 science teams. Second only to the orbiter imaging team in size, the group has no scientific instruments of its own on any of the four spacecraft, yet its work will aid geologists, astronomers, seismologists, chemists and a host of others.

The radio science team, headed by William H. Michael of the NASA Langley Research Center in Virginia, does almost all of its work by studying the normal Viking-to-earth communications channels. Not for the messages they carry, but for what the radio beams themselves tell about the positions of the spacecraft, and for the ways in which the signals are changed as they pass through the Martian atmosphere, graze the planet's surface, pierce the fringes of the sun and traverse interplanetary space.

Thanksgiving Day, for Michael's team, will be a big event indeed. For months, the motions of the planets have been approaching a point at which the sun will be directly between Mars and the earth, an alignment known as solar conjunction. As Viking's radio path to earth has moved closer and closer to the sun, solar interference has had an increasing effect on the radio signals in both directions, producing noise or static that shows up as a growing "bit error rate" in the messages. For solar conjunction, Thanksgiving Day is dead center.

The sun's effects began showing up in Viking's messages as early as September, and some project engineers predicted that communications with the spacecraft would be cut off for as long as two weeks on either side of conjunction. But in fact, says Michael, the blackout may become total only for "a day or so," and perhaps not at all. The rate at which it develops and the changes it produces in the frequency, amplitude and phase of the spacecraft signals, together with irregular variations produced by changes in the sun's actvity, are all grist for the radio team's mill. Data from these changes will lead to improved measurements of the extent of the corona, the density and velocity of solar plasma streams and other findings.

Other parts of the team's work are much closer to Mars. The two Viking landers, for example, would be lost on the planet but for their radio signals, since they are too small to be photographed by the orbiters. Careful tracking of the signals as the planet and the orbiters move, however, has pinned down lander 1 at 22.48°N by 47.9°W and lander 2 at 47.97°N by 225.7°W, with further refinements to follow. Furthermore, the radius of Mars at the two sites is now known to within as little as 100 meters: 3,389.38±0.1 kilometers for the first site, in the Chryse basin, and 3,381.88±0.25 kilometers for lander 2's resting place in Utopia.

The same equations which pinned down the landers have also produced refined estimates of the orientaton of the planet's axis of rotation (right ascension 317.34°, declination 52.71°; an order of magnitude more precise than calculations enabled by Mariner 9) and of its rate of spin. All these measurements, including the lander locations, are produced together by simultaneous equations, since none can be figured out without taking the rest into account. The spin rate, says Michael, has now been timed to within milliseconds—a severalfold improvement over Mariner 9—and another year or two of tracking may reduce the uncertainty by another factor of 10.

Such extended tracking, he adds, may

even make it possible to measure irregularities and precession in the polar motion, which in turn could lead to estimating the planet's moment of inertia and from that its bulk density distribution. In fact, he says, if the spin rate could be narrowed down to within microseconds (an extremely slim possibility, he points out), it might be possible to measure the seasonal change in mass distribution as the atmosphere freezes out and thaws at the poles.

The three drifting "walks" by the orbiters have been particularly valuable to the radio team in refining the shape of the Martian gravitational field, including the subtle "harmonics" which indicate the degree to which the planet is flattened at the poles and pear-shaped on polar or equatorial axes. In January, orbiter 2 is to be shifted into an orbit whose low point comes as close as 300 kilometers to the surface, once per orbit, for up to six months. Besides providing striking photos of the surface (with resolution as fine as 10 meters), the low passes should yield precise tracking data about local gravity anomalies, reflecting mass concentrations beneath the surface such as the one discovered by Mariner 9 as it passed over the Tharsis uplift zone, or bulge.

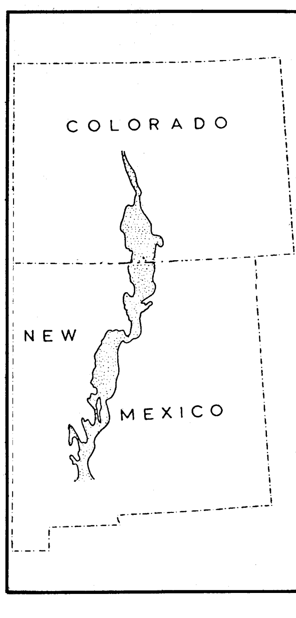
There are even radio measurements relating to the surface composition. When the lander's radio path to the orbiter just grazes the surface on the way, changes in its amplitude reflect the dielectric constant and conductivity of the material it is grazing. Viking measurements suggest a dielectric constant of about 3.5, consistent, says Michael, with some sort of pumice or tuff. Water content also affects the signal, he says, and it is just barely possible that seasonal water changes late next year could be detected in the data.

Even the earth may be better understood from Viking's radio studies, using the essentially fixed signals of distant quasars as well as those of the Viking craft to pin down the earth's axial and orbital motions. Finally, general relativity will get a checkout, as Michael's team determines how much the spacecraft signals are slowed as they pass near the sun, and how the precession rate of Mars's orbital perihelion varies. □

Whoopers up

More whooping cranes are migrating this year than at any time since 1938, the Canadian Wildlife Service has announced. The increased number signals the success of a "foster parent plan" attempted during the last couple of years, in which eggs from whoopers in Canada's Northwest Territories were hatched by sandhill cranes in Idaho. Of the 14 transplanted eggs, three juveniles and three yearlings survived to join this year's migration, bringing the known world population of whooping cranes to 95. □

Rio Grande Rift: Crack in crustal plate



Geological Society of America

Rio Grande Rift: Pulled-apart crust, magma chambers and a model for mountain-building.

From south-central Colorado southward 850 kilometers through nearly all of New Mexico runs a series of basins created where linear blocks of the earth's crust have dropped down between a line of parallel faults. This series of basins used to be known as the Rio Grande depression, for the river that flows through most of its length. Recently geologists have been calling it by a more dramatic name: the Rio Grande Rift. For it is now evident that the feature marks the site of a crack in the North American crustal plate, the huge slab of the earth's upper surface that carries on it the western Atlantic Ocean and virtually all of the North American continent.

At the annual meeting of the Geological Society of America last week in Denver a dozen presentations by 29 scientists from 11 institutions reported results of new studies of the rift. The studies probed the rift with a vast array of geological and geophysical instrumentation. The reports show that the rifting process is still going on, that the rift's western margin has abnormally high heat flow, that much of the rift represents an anomalous zone of crustal thinning and that one segment of the rift area has lying beneath it a body of magma 1,000 square kilometers in extent. Finally, a theory of continental rifting applied to the Rio Grande Rift, presented at the meeting, explains in considerable detail the observed structure of many of the mountains extending along the sides of the rift through Colorado and New Mexico.

The rifting began about 30 million years ago, reports C. E. Chapin of the New Mexico Bureau of Mines and Mineral Resources, when regional extension began to pull the continental lithosphere apart along a major north-trending zone of weakness. "It began as a simple pull-apart structure," says Chapin. The Colorado Plateau, the eastern margin of which abuts the rift, began to be pulled apart from the rest of the continental mass. There was extensive volcanism in the area for the next 10 million years, then a lull, then renewed thermal activity about 12 to 14 million years ago.

The modern topography, says Chapin, was born after 9 million years ago and before 3 million to 4 million years ago. This period was marked by "a tremendous surge of uplift and block faulting." Volcanism was sharply accelerated about 5 million years ago, and since then basalt flows have dotted the rift from Alamosa, Colo., to the Mexican border. Arrangement of drainage to form the ancestral Rio Grande River began before 3 million years ago, probably as a result of runoff from the newly elevated mountains.

Some of the most intense scientific interest associated with the rift concerns evidence for a magma chamber beneath the surface near Socorro, N.M. Magma chambers have many implications: They are obvious potential sources of geothermal heat, they raise questions whether they might eventually become a full-fledged volcano and their heat may be important in concentrating minerals.

Alan R. Sanford of the New Mexico Institute of Mining and Technology first reported evidence for the Socorro magma body in 1973. Last week in Denver, he and five colleagues reported new evidence based on microearthquake investigations carried out from April 1975 to September 1976. Together, the data define the upper surface of a magma body 18 kilometers beneath the rift and at least 1,000 square kilometers in area. Only the body's southeastern margin, which is highly irregular, has been clearly detected. From its crest beneath the Socorro Mountains the magma body's upper surface dips sharply to the east and west to depths of at least 20 kilometers.

Sanford also has new evidence of a small shallow magma body about 12 kilometers southwest of Socorro and of the possible existence of several other small magma bodies at depths of less than 10 kilometers.

Repeated analysis of leveling measurements in the Socorro vicinity by Robert Reilinger and Jack Oliver of Cornell University reveals a zone of major uplift that overlies and correlates spatially with the area above the proposed magma chamber. The surface has been rising at an average relative velocity of 5 millimeters per year. "This feature is one of the most clearcut and striking anomalies of this scale ever detected by leveling in the United States," they report. They suggest that the uplift in the Socorro area could result from expansion of the magma chamber.

Other striking evidence comes from a new scientific program for study of the