Caltech's John Racs quite properly wears heavy plastic gloves for protection as he inserts a probe into the brain of an electric ray. Unfortunately, one of the gloves had a small hole, and Racs repeatedly received 200-volt shocks. The fascinated onlooker is high school teacher Gary Stellern, whose oceanography class hauled in the animal.

Neurobiological Research with the Electric Ray

On an oceanography field trip this spring a boatload of students from John Muir High School in Pasadena hauled in a hefty specimen that turned out to be a 65-pound *Torpedo californica*—an electric ray indigenous to this part of the Pacific. Their teacher promptly put in a call from the boat to Caltech, and when the ship docked, two members of the Institute's neurobiological research group —Richard Vandlen, research fellow in chemistry, and technician John Racs—were ready to remove the ray's electric organ for use in their research. As a matter of fact, Vandlen and Racs are routinely called to come and pick up torpedoes, which are netted along with the anchovies fishermen catch for bait. Rather than throw the dead rays back into the ocean, the fishermen bring them back and freeze them, and every few weeks the researchers go down and collect whatever is in storage.

What made this particular ray worth an extra trip was its size; the average ray weighs only about 40 pounds. The electric organ is a modified muscle comprising 20 to 25 percent of the ray's total body weight. It is specialized for the production of electricity—amounting to 200 volts, 50 amperes—which is equal to about 10,000 watts, or enough to light a house momentarily.

The rays are used at Caltech in studies of how nerve cells are connected with each other and with muscle cells. The objective of this research is to elucidate how nerve cells transmit signals, and eventually to understand the chemical basis of the function of the nervous system.

The point of contact between two nerve cells, or a nerve cell and a muscle, is called a synapse. When an impulse or message is passed along a nerve fiber, it reaches the synapse, where it triggers the release of a chemical compound, acetylcholine. This compound, also called a transmitter substance, elicits a response from the neighboring cell: A nerve cell will fire another impulse, a muscle cell will contract, a gland will secrete its product.

Very little is known about how the synapse actually works. This is largely due to the fact that tissues containing large quantities of synapses, like the brain or spinal cord, are very complex and contain a great number of different types of synapses. Tissues that contain a single type, like muscle, normally have very few synapses—which renders chemical investigation almost impossible.

However, nature has invented a tissue with a synapse concentration about 1,000-fold that of normal muscle tissue. These tissues are the electric organs of certain species of fish such as the electric eel, a freshwater animal from the Amazon basin; and the electric rays, which live in all of the world's oceans. One of the most highly innervated electric organs is that of the California ray, *Torpedo californica.* Large animals of these species can have electric organs totaling ten pounds and more; every gram containing 20 times more nerve-ending material than a gram of eel organ which, in turn, is much more richly innervated than ordinary muscle.

At present the main research effort in this field is directed toward a better understanding of what the transmitter substance does to the target cell. It is known from physiological investigations that the transmitter has to interact with a specific membrane component for a response—say, a muscle contraction—to occur. This membrane component, usually referred to as "transmitter receptor," obviously plays a key role in nerve cell interaction.

Two years ago British scientists succeeded in extracting the "transmitter receptor" from the electric tissue of a ray. Recently the group at Caltech worked out a procedure to purify the receptor from all the other membrane components. For the first time sufficient amounts of pure transmitter receptor have become available for detailed study. To continue these investigations, however, large quantities of torpedo organ will be required. The more electric rays are available, the more work can be done toward the elucidation of the fundamental mechanisms of nerve cell action and toward the investigation, prevention, and treatment of a variety of nerve and muscle diseases. □