Sabini and Silver doubt that lectures will teach people to disobey immoral commands. Classroom role-playing and other practical experiences, they contend, are needed to teach the young that "doing the morally right thing does not always 'feel' right."

## SCIENCE & TECHNOLOGY

### *Educating Snails*

"Aplysia and Hermissenda" by Stephen S. Hall, in *Science 85* (May 1985), 1101 Vermont Ave. N.W., 10th Floor, Washington, D.C. 20005.

Snails are a delicacy to some, a slimy nuisance to others. But to two American scientists, these mollusks are providing tantalizing clues to the mystery of human thought and memory.

Daniel Alkon, of the Marine Biological Laboratory in Woods Hole, Mass., has devoted most of his career to studying snails, specifically the genus *Hermissenda*, writes Hall, a *Science 85* contributing editor. Alkon subjected the snails first to bursts of light and then to rotation. Slowly he conditioned them to contract when a light is shown as if rotation were imminent—in the same manner that Ivan Pavlov, the 19th-century Russian physician, taught dogs to salivate at the ring of a bell.

Alkon traced the *Hermissenda*'s ability to "learn" to a change in their neurological chemistry. Every time certain snail neurons are stimulated, the flow of potassium through the cell membrane is altered. Repeated long-term arousal disrupts the cell's "resting state," the way it was before stimulation, allowing it to "associate" the sensation of light with rotation.

Alkon believes humans learn by constructing "whole sets of associations" in a manner similar to the snails', "even if it's the most complex association, such as remembering riding a bicycle or remembering what your father's and mother's faces looked like."

Eric R. Kandel, a Columbia University neurobiologist expected soon to win the Nobel Prize, began analyzing nerve clusters in *Aplysia* snails in 1962. Since then, he has identified many neurological changes that take place during "habituation" (an underreaction) and "sensitization" (an overreaction) to a stimulus. Kandel believes, in contrast to Alkon, that learning mainly involves a chemical change in nerve synapses (where nerve endings meet) rather than in the cell membranes. Kandel's theory may help to explain how the one trillion neurons in a human brain can associate and remember daily experiences.

Hall notes that Alkon and Kandel both believe "evolution latches onto hardy mechanisms and that what works for invertebrates might also work . . . with obvious improvements . . . in humans." The two scientists are still a long way from proving that human learning follows the pattern of the snail's response to stimuli. But last year Alkon reported discovering startling similarities between some learning mechanisms in *Hermissenda* and those in rabbits.

Why should researchers continue to study snails instead of other creatures? Because, says William Quinn, a fellow neuroscientist, snails are "built like an old Philco radio, with simple circuits and large, easily identifiable components."

## *Tinkerers And Scientists*

"Science and Technology: The Driven and the Driver" by John P. McKelvey, in *Technology Review* (Jan. 1985), Massachusetts Institute of Technology, Bldg. 10., Cambridge, Mass. 02139.

Scientists and technologists have lived off each other's creations for centuries. But scientists always seem to get the credit. McKelvey, a physics professor at Clemson University, maintains that technologists have unfairly been pushed to the back seat, that they have furthered scientific progress no less than have scientists themselves.

Hans Christian Oersted's discovery of magnetic fields in 1819 would not have been possible without "voltaic cells," or batteries—a purely technological creation. Alessandro Volta (1745–1827) built a battery from discs of dissimilar metals separated by pads moistened with salt solution. It generated current, although Volta did not know why. Not until 40 years later did the physicist Michael Faraday correctly explain how batteries operated.

The great discoveries of the 15th and 16th centuries, too, grew out of two simple inventions: the clock and the lens. Newtonian mechanics, the stepping stone to modern physics, became possible when small time intervals could be measured. And telescopes, which allowed astronomers to grasp the true shape of our solar system, depended on well-ground lenses. Galileo, who is credited with building the first telescope in 1609, probably got the idea from an optician in the Netherlands, who received a patent in 1608, McKelvey says.

Isaac Newton found that refracting telescopes (with multiple lenses) broke up light like a prism and abandoned them in 1666 for reflecting telescopes (with mirrors). But John Dolland, a self-educated British optician, proved Newton wrong by designing achromatic telescopes, which showed clear images without refractions. His discoveries in 1758 led to the microscope, which allowed biologists to study cells and eventually pioneer microbiology, cytology, and immunology.

Other endeavors also owe more to new instruments than to revolutionary changes in thought. Artists and chemists with little knowledge of light or physics invented photography. Lee De Forest's experiments with vacuum-tube triodes in 1904 led to radio. The classic examples of an uneducated "tinkerer's" contribution to technology: Thomas Edison's phonograph (1877) and incandescent lamp (1879).

McKelvey laments the modern rise of competitive group research that discourages adventurous spirit. Through neglect, he believes, society is driving tinkerers like Edison into extinction. What might help? More private and public support for "a few 'obviously' unsound projects and 'clearly' unprofitable lines of thought."