Nitschke, "perhaps two to three orders of magnitude increase in intensity, at a cost of more than $50 million and less than $200 million," was first proposed in 1989 as part of the Department of Energy's Nuclear Science Advisory Committee long-range plan.

If such a machine gets built, it may have constituents well beyond physicists—nuclear chemists, for example. Walter Loveland of Oregon State University points out that with an intense enough beam, researchers could routinely produce elements like 104 and 106. These elements have already been identified, earning them a place in the periodic table, but the proton-rich isotopes made so far have a half-life of barely a few minutes. Theorists predict that isotopes richer in neutrons could have a 10-fold longer half-life.

Chemists would love to get their hands on longer-lived isotopes, explains Loveland, because these heavy exotics break the rules of ordinary chemistry. In these heavy elements, he says, "the nucleus is so heavy and the electrons so tightly bound around it" that the electron velocities become relativistic—they approach the speed of light. "Once electrons become relativistic in behavior," he says, "the kinds of chemistry we talk about to students doesn't work any more. If we can get significant quantities of nuclei which stay around for a while, it will mean an awful lot for both atomic physics and chemistry."

Then there is the Holy Grail of nuclear chemistry, which is creating hitherto undiscovered superheavy elements above element 109, a territory theorists speculate might harbor stable elements. As Tanihata explains, researchers have been trying to make these fragile superheavies by colliding heavy nuclei, such as nickel and bismuth—but instead of sticking together, the colliding nuclei generally shatter. If researchers could generate beams of neutron-rich heavy isotopes with neutron halos like that of lithium-11, says Tanihata, "you might be able to make a soft landing." The halo might act as a kind of atomic-scale cushion for the collision.

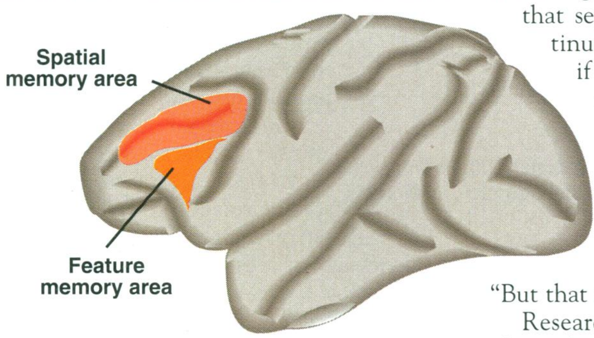
Applied scientists will also be lining up, judging from their interest so far. Ravn says that 30% of the projects at ISOLDE, at CERN, are already in applied science: efforts to make new semiconductor devices, by doping semiconductors with radioactive nuclei that can then decay into other elements, or to develop and study new radioisotopes for diagnostics and cancer treatment. Adds Sherrill, "As the science develops, we'll be able to give you nuclei of any element and any half-life to use in whatsoever science you want—biology, medicine, condensed matter, whatever. You say, 'I have a process that lasts 10 milliseconds.' We say, 'Okay, here's a 10-millisecond nucleus, or a whole bunch of nuclei.'" Exotic nuclei will be exotic no more.

–Gary Taubes

NEUROSCIENCE

Making Modular Memories

The brain's real estate keeps getting subdivided. Neuroscientists have been busy for the past three decades parceling up the visual cortex, where the brain starts to process signals coming in from the eyes, into ever-smaller, specialized plots. Some of these areas respond to color, some to shape, and some to movement. But when we think about objects we recall all of these qualities, so it seemed logical for scientists to assume that, higher up in the brain, this disparate information gets spliced together in areas where memories are formed and cognition takes place. But now a team from Yale University has shown that similar subdivisions exist even in the prefrontal cortex, which is involved in forming temporary, working memories. Some areas chiefly respond to "what" an object was, while others respond to "where" it was located.



Memory maps. Areas in the prefrontal cortex seem to recall different aspects of an image.

ILLUSTRATION: L. OWENS

"Memory is modular; it's not all in one device," says neuroscientist Patricia Goldman-Rakic, one of the researchers. "This is the first physiological evidence separating out those modules." She and her colleagues Fraser A. Wilson and Séamas P. Ó. Scalaidhe report on page 1955 of this issue that neurons in two regions in monkeys' prefrontal cortex respond to different visual cues. Neurons in an area known as the inferior convexity (IC) retain information about an object's color and shape for a short period after the object has disappeared from view. Neurons in an adjacent area encode an object's location.

"This is really right on the forefront" of memory research, says Jon Kaas, a neuroscientist at Vanderbilt University in Nashville, Tennessee. Kaas notes that these results are the first good functional evidence showing that separate perceptual pathways continue into the prefrontal cortex. And if further studies reveal working memory centers tied to the other senses, Kaas believes it would suggest that memories are divided up by their qualities much like image qualities—motion and shape, for example—are divided up in other cortical regions. "But that is a big if," he says.

Researchers had already traced out a physical path of neuronal connections going from spatial areas in the visual cortex, in the rear of the brain, up to the prefrontal cortex. They had also discovered a similar path leading from visual areas that react to features. Wilson and his colleagues then set out to determine whether function matched anatomy. They began by teaching monkeys two different visual tasks. In one, the monkeys were trained to stare at a spot in the center of a video screen while an image flashed at one of several locations on the screen and then disappeared. A few seconds later, a cue on the screen signaled the monkeys to move their gaze to where the image had been, an indication that they retained the information about its location. In the second test, the location of the image—a square—remained constant, but the pattern within the square changed. The monkeys were trained to wait until the image disappeared, and then move their eyes to the left if they saw one pattern or to the right if they saw another, indicating they remembered information about an object's features.

Throughout the tests, the researchers used microelectrodes implanted in the monkeys' prefrontal cortex to record the activity of individual neurons in the IC and in an adjacent area that surrounds a feature called the principal sulcus. The investigators found that when they kept the image the same but changed its location, neurons surrounding the sulcus became active during the delay period, while neurons in the IC tended to remain quiet. But when the image's pattern varied and its location remained constant, the delay period brought neurons in the IC to life, but the neurons around the sulcus didn't respond.

Finding that working memory is specialized in at least two ways, say other scientists, shows that such memories appear to form in a parallel fashion, and that there's no central memory manager putting everything together. "The assumption in the past has sort of been that there will be a next level [of processing] that will reintegrate everything," says John Allman, a neurophysiologist at the California Institute of Technology. "But there just isn't much evidence for that."

–Robert F. Service

Robert F. Service is a science writer in New York City.