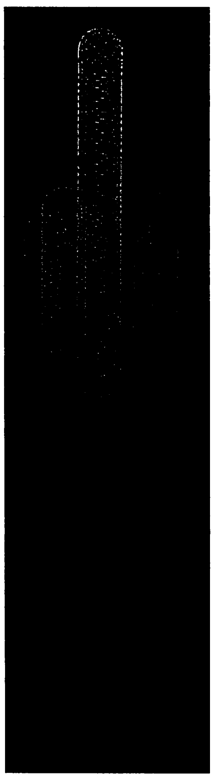
Texas, reported a new chemical process for making single-walled nanotubes (SWNTs), potentially by the kilogram. The scheme combines simple and abundant gaseous precursors that react to form iron-based catalyst particles, which then promote the growth of the nanotubes. And because that type of gas-phase synthesis is akin to the way bulk plastics are made today, the new scheme has clear potential to be scaled up to make industrial quantities. "Within the next year we should easily be able to produce 10 kilograms of this stuff [in the lab]," says Richard Smalley, the leader of the Rice team, who shared the 1996 Nobel Prize in chemistry for his part in the discovery of fullerenes, a class of three-dimensional carbon molecules that includes nanotubes.

"It's a very important development that nanotubes can be made in big quantities," says Walt de Heer, a nanotube expert at the Georgia Institute of Technology in Atlanta. "It implies that the price [of nanotubes] will come down, and this could allow their use as large-scale construction materials." Still, de Heer cautions that inexpensive ingredients don't guarantee low costs. The round fullerenes known as buckyballs can be made from cheap starting materials, he points out, yet they remain more expensive than gold.

Smalley's new scheme isn't the first to use catalysts to create nanotubes. In 1995, his team at Rice came up with a method that blasts a graphite target with lasers in the presence of catalytic metal particles. The intense heat generated by the lasers blasts the graphite into a vapor of carbon atoms, which the metal particles then help to coalesce into nanotubes. But the laser apparatus is expensive and has yielded only about 300 grams of SWNTs in the past 2 years. What's more, the tangle of SWNTs that the process creates is contaminated with about 10% carbon soot, which must then be removed in another step to yield the pure nanotubes.

In search of better results, Smalley and his postdocs Michael Bronikowski and Peter Willis took a hint from the bulk-plastics industry. They looked for ways to make both the catalyst and nanotube starting materials gaseous. The key turned out to be a molecule called iron pentacarbonele, which has an iron atom surrounded by five carbon monoxide (CO) groups. They spray this compound along with additional CO into a chamber heated to about 1000°C. The heat rips the CO arms off the iron atoms, leaving the lone atoms energetically unhappy and eager to bond with one another to form more stable clusters. And—as in the laser SWNT scheme—those metal clusters excel at producing SWNTs. Meanwhile, the high temperature also causes CO molecules to react with one another to form the more stable CO_2, leaving behind lone carbon atoms, which quickly find the iron nanoparticles and begin to grow a SWNT. "The SWNTs just fall out of the chamber in an essentially pure form," Smalley says.

Still, Smalley cautions, "this isn't the ultimate" when it comes to making SWNTs. The tubes, he says, wind up as a tangled mat rather than perfectly aligned fibers. They also vary slightly in diameter, a drawback that can create tubes with a range of electronic properties. But Smalley and colleagues are confident that they can iron out the glitches. Last week, they announced that they were forming a new company—Carbon Nanotechnologies Inc.—to commercialize their SWNT production process. If their scale-up plans pay off, they may finally turn nanotubes from a research curiosity into the technological successor to plastics. —ROBERT F. SERVICE



High hopes. Gas-phase process might yield nanotubes at nanoprices.

CREDITS: (LEFT TO RIGHT) CENTER FOR NANOSCALE SCIENCE AND TECHNOLOGY/RICE UNIVERSITY; THE COULSTON FOUNDATION

NEUROSCIENCE

Video Game Images Persist Despite Amnesia

The video game Tetris can be found on computers in almost any lab; grad students need their entertainment, after all. But few researchers have put the game to more explicitly scientific use than Robert Stickgold and his colleagues at Harvard Medical School in Boston. On page 350, they report the results of new work in which they used the game—which involves spatial reasoning to slot falling blocks strategically into place (see diagram)—to study how the brain reviews what it has learned.

The researchers found that people who have just learned to play Tetris have vivid images of the game pieces floating before their eyes as they fall asleep, a phenomenon the researchers say is critical for building memories. Neuroscientists have long known that memory consolidation goes on during sleep. But much more surprisingly, the team also found that the images appear to people with amnesia who have played the game—even though they have no recollection of having done so. Apparently, Stickgold says, the am-

ScienceScope

O Give Me a Home The fate of 288 chimpanzees used for research remains uncertain after the National Institutes of Health (NIH) rejected a proposal from their current caretakers to continue housing them.

The NIH assumed ownership of the chimpanzees in May after a settlement with the U.S. Department of Agriculture's office of animal welfare required the Coulston Foundation of Alamogordo, New Mexico, to give up ownership of the animals (*Science*, 12 May, p. 943). NIH then announced a competition for their care, to which Coulston applied. But on 5 October NIH sent a letter to Coulston, saying that an outside review committee had found its proposal unacceptable. The decision leaves Coulston temporarily in charge of the animals.

The latest decision is "an extension of NIH's mismanagement and irresponsibility," says Suzanne Roy, program officer of In Defense of Animals (IDA), a California-based animal-rights group. "We're working as fast as we can" to recruit another caretaker for the animals, counters John Stranberg, NIH's director of comparative medicine.

Sausagemakers The White House and Congress reached a tentative deal late last week on a 2001 spending bill that contains good news for NASA and the National Science Foundation (NSF). But at press time officials at both agencies were still waiting to learn what strings had been attached and how legislators planned to finish their work.

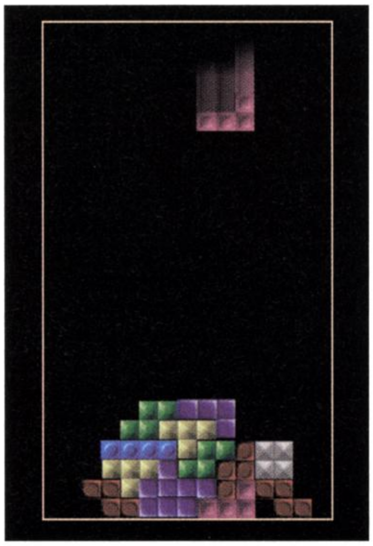
The bill would give NSF a 13.5% increase, to $4.4 billion, from its current $3.9 billion budget. That's close to the Administration's 17.3% request and much higher than the versions passed earlier this year by the House and a key Senate committee.

The $14.3 billion for NASA would be $250 million above the request and a sharp improvement over earlier bills, which were below what the agency had proposed (*Science*, 22 September, p. 2018). The additional funding would take care of most—although not all—of the pork-barrel projects larded into the conference bill by lawmakers. But it's not expected to rescue a Pluto mission or other moribund space science efforts.

Contributors: Richard Kerr, Robert Koenig, Gretchen Vogel, Andrew Lawler and Jeffrey Mervis

nesics still have access to perceptual memories in the cortex, despite having damage to the hippocampal regions of their brains that prevent them from recalling the game.

The finding suggests that the "parts of the brain responsible for the inability to learn must be different from those responsible for the images," says Richard Haier of the University of California, Irvine, whose previous brain imaging studies of Tetris players showed that many brain areas become active when novices first learn the game.



Mind the gap. Tetris player aligns falling blocks to fill gaps as layers build up at bottom of screen.

CREDIT: BLUE PLANET SOFTWARE

In the current work, Stickgold and his colleagues focused on Stage 1 sleep, the stage at which, as Stickgold explains, "your significant other pokes you and says you're asleep, and you say 'No, I'm not.' " In this case, a researcher did the poking. Novice Tetris players spent hours learning the game during the day, and then when they went to bed, researchers woke them up repeatedly during the first hour of sleep to ask what was on their minds (aside from wanting to sleep in peace). Nine of 12 people without amnesia said they'd seen images of Tetris blocks, sometimes rotating and sliding into place as they do during the game.

The researchers also tested five people who had extensive damage to the hippocampus and surrounding areas of the temporal lobe that prevented them from building new so-called explicit, or declarative, memories. For example, the subjects had no memory of the game (or the experimenter) from session to session. And even though other studies have shown that people with amnesia can learn new skills, such as tracing a shape seen only mirror-reversed, they didn't learn Tetris very well. "With complex skills like [those required by] Tetris, subjects may have to remember things declaratively," says memory researcher Larry Squire of the University of California, San Diego. Because the subjects probably can't keep the rules of the game straight, they don't have the opportunity to get faster and more accurate.

But even though the subjects don't remember the game, don't get better at it, and have no idea why they're being woken up in the middle of the night, they reported seeing what sound remarkably like Tetris pieces while they're drifting off to sleep. For instance, one reported seeing "images that are turned on their side. I don't know what they are from. I wish I could remember, but they are like blocks."

Why are people replaying Tetris in their sleep? Stickgold speculates that during sleep, the brain cements connections between a day's events and stored memories. This theory is bolstered by reports from some study participants who, unlike the novices, had played Tetris years before. These return players reported sleep images that portrayed the graphics from versions of Tetris they'd learned on, not the Tetris graphics they'd seen that day. The new experience, Stickgold says, calls up old memories that the brain interconnects.

Not all aspects of the experience are replayed during Stage 1 sleep, however. People seem to "extract what's relevant from an event and dump the peripheral details," Stickgold says. In Tetris, for example, the spinning pieces and disappearing lines are crucial parts of the game, but the computer monitor, surrounding room, and keyboard aren't important—and none of the Tetris players reported imagining them in their sleep.

The amnesia patients, because of the damage to their hippocampi, can't form the kinds of connections that would allow them to recall the game. But even so, they still retain perceptual memories, which float around in the cortex and return, disconnected, during sleep. —LAURA HELMUTH

IMMIGRATION POLICY

Growth in Visas Boosts NSF Education Programs

Last week Congress rushed through an immigration bill that gives a big boost to education programs at the National Science Foundation (NSF). The measure, which almost doubles the number of skilled foreign workers eligible for high-tech U.S. jobs under so-called temporary H1-B visas, marks a hard-fought victory for high-tech companies scrambling for talent. In addition, it provides more than $100 million to help NSF tackle what policy-makers say is the real problem: the need for more homegrown scientists and engineers.

"This bill begins to address our long-term challenge: ensuring that there are enough Americans with the necessary skills to fill these jobs," declared Senate minority leader Tom Daschle (D–SD) during floor debate on 3 October before a 96–1 vote on the bill, S. 2045. The House passed the Senate's version a few hours later on a voice vote.

The bill raises the annual ceiling on temporary visas for high-tech workers to 195,000 for the next 3 years from the current level of 115,000. Under the current law, the ceiling would have dropped to 65,000 in 2002. The bill sets no limit on the annual number of workers, estimated at up to 20,000, hired by universities and nonprofit research organizations.

The fees paid by industry to apply for the visas are expected to generate an estimated $275 million a year, with 55% going to the Labor Department for worker training programs. NSF will receive 38.2%, and unofficial estimates put its expected annual take at $105 million, a big jump from the $30 million it had budgeted for 2001. The new fee is $1000, double the existing amount. The increase came in a separate last-minute bill pushed through by supporters this week after legislators deferred to the House's constitutional right to initiate revenue measures and stripped the Senate measure of similar language.

The bill directs NSF to spend about 60% of its money on elementary and secondary school activities, ranging from new curricula and improved teacher training to after-school programs and partnerships with industry. The funds will greatly expand a $3 million after-school science enrichment program, begun this year, that plans to make its first awards next spring. The program, known as After School Centers for Exploration and Discovery (ASCEND), attracted three times the expected number of preliminary proposals, despite a requirement that applicants add at least 30% to the government's contribution. "We hit a nerve," says NSF's Jane Kahle. The bill also provides $20 million over 5 years for after-school technology training programs to be run by the Boys and Girls Clubs of America, which are already eligible for the ASCEND money. And it asks NSF to do a study of the differential access to high technology, the so-called "digital divide."

The rest of NSF's visa money would go to enlarge a college scholarship program that made 110 awards to universities during its initial competition last spring (*Science*, 7 April, p. 40). Each award typically allows a school to provide a 2-year stipend to 40 low-income students seeking associate, undergraduate, or graduate degrees in computer science, engineering, or mathematics. The legislation also boosts that annual stipend from $2500 to $3150, but NSF officials say that it is too early to know how the influx of funds will affect the overall size and number of institutional awards. —JEFFREY MERVIS