SCIENCE NEWS of the week

Babies Add Up Basic Arithmetic Skills

Babies possess many obvious aptitudes — drooling, crying, soiling diapers, and evoking unbounded love from their parents. You can now append a more surprising talent to that list, according to a report in the Aug. 27 Nature: Infants as young as 5 months of age can add and subtract small numbers of items.

"My working theory is that humans are innately endowed with a mental mechanism devoted to quantifying discrete entities, and this mechanism is already operating unconsciously in infants," asserts psychologist Karen Wynn of the University of Arizona in Tucson.

In a commentary accompanying Wynn's report, psychologist Peter E. Bryant of the University of Oxford in England calls her paper "a notable event in the history of developmental psychology" that presents "apparently cast-iron evidence" for rudimentary mathematical reasoning by infants.

Research exploring babies' perceptual and mental capacities has ballooned in the past 20 years. Studies indicate that babies see individual objects within an array of items, visually track moving objects, and know that an object exists when it moves behind a barrier. Investigators have also found that infants realize when a small number of drumbeats matches an equal number of objects shown on a slide. Babies also respond to changes in the number of a set of objects.

The perception of a small number of items in the absence of explicit counting, referred to as subitization, may stem from either numerical calculations or a general quantity judgment unrelated to mathematical reasoning.

Most studies of how infants think — including Wynn's — rely on a "looking-time procedure": Babies tend to look markedly longer at new or unexpected stimuli than at recently presented or familiar stimuli.

Wynn first studied 32 baby boys and girls, all around 5 months of age. A "1 + 1" group saw a rubber Mickey Mouse doll placed on a table and then obscured by a screen. Next an experimenter placed a second doll behind the screen, in full view of each infant. A "2 − 1" group saw two dolls placed on a table and then obscured by a screen, followed by an experimenter removing one doll. At that point, the screen was lowered for both groups.

Each infant viewed the addition or subtraction six times. In half the instances, an incorrect number of dolls appeared upon removal of the screen, corresponding to "1 + 1 = 1" or "2 − 1 = 2." The other trials presented the correct number of dolls. Before the trials began, Wynn also established the baseline amount of time each baby spent looking at one doll and at two dolls.

Both groups looked significantly longer at the incorrect number of dolls in test trials, and allotted less, roughly equal time to looking at one or two dolls in baseline tests. The same pattern held for another 16 infants, also around 5 months old, tested in the same way, Wynn says.

Infants apparently expected the correct number of dolls to emerge from behind the screen and experienced surprise when they saw a different number, she argues. However, since the number of dolls in incorrect trials equaled the number shown before addition or subtraction, infants may only have noticed an unspecified numerical change with no expectations about the size or direction of the change.

A third study suggested that infants can indeed add up small numbers. Wynn exposed 16 infants between 4 and 5 months of age to the "1 + 1" trials, but the final number of dolls revealed behind the screen was either two or three. Both results differed from the initially presented number of dolls. Infants looked substantially longer at three dolls in test trials, but not in baseline tests with two and three dolls, Wynn says.

Several unpublished studies directed by Renee L. Baillargeon, a psychologist with the University of Illinois at Urbana-Champaign, find comparable calculation skills among 10-month-olds.

Both sets of results also suggest that subitization involves a counting process, supporting contentions that some animals, including birds and apes, calculate small quantities in a way linked to human counting (SN: 5/23/87, p.334), Wynn adds.

Infants' limited short-term memory undoubtedly restricts their counting ability, she notes. Wynn is now testing 5-month-olds on "3 + 1" and "3 − 1."

Wynn's third experiment convincingly demonstrates addition by infants, but she needs to conduct the same control for subtraction, Bryant asserts.

Infants probably do not understand that if, for instance, 3 + 2 = 5, then 5 − 3 = 2, he holds. But Wynn's work opens the way to investigating this assumption, Bryant adds.

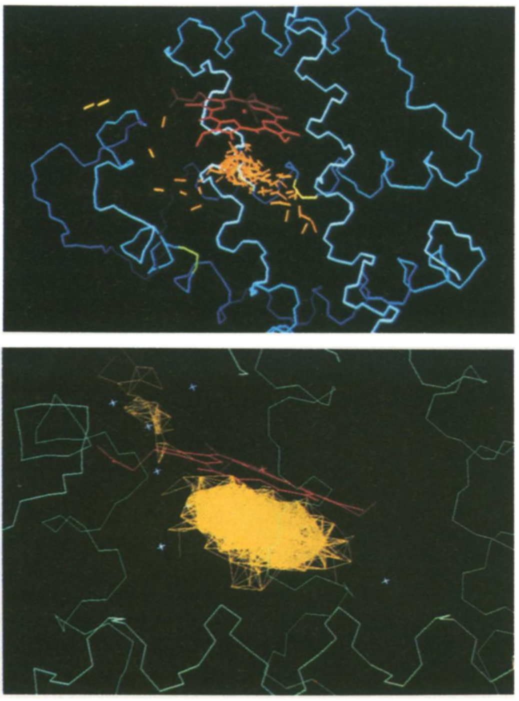
— B. Bower

Computer charts path of diffusing molecules

Computer simulations have given chemists a sneak preview of how small molecules worm their way into and out of larger ones. That preview, especially when combined with genetic engineering techniques, can guide researchers in attaining proteins for specific uses.

Two computational chemists have modeled carbon monoxide molecules exiting leghemoglobin, a plant protein that resembles human hemoglobin but which acts to trap rather than transport oxygen. Leghemoglobin has mystified researchers for years because the sites where oxygen or carbon monoxide bind to heme proteins lie deeply buried and seem inaccessible.

The simulations rely on new techniques that simplify the task of tracking the movements of the thousands of atoms that make up proteins, says Ron Elber of the University of Illinois at Chicago. He and Illinois colleague Gennady Verkhivker calculate that it takes just a few nanoseconds for two-atom molecules to escape from this protein. That's at least 10 times faster than those molecules can get out of similar proteins such as myoglobin, Elber says.



Elber *et al.*/Univ. of Ill. at Chicago

Top: Simulation creates 80 molecules (orange) that try to escape from the heme core (red) of the protein (blue). Bottom: Time-lapse image traces one molecule's path (yellow) away from the heme (red) and out of the protein (green).

The molecules leave in two steps, the Illinois chemists and biochemist Quentin H. Gibson of Cornell University reported this week at an American Chemical Society meeting in Washington, D.C. First a carbon monoxide must push aside and move around a six-atom ring belonging to one of the protein's amino acids, a phenylalanine. That ring traps the carbon monoxide in an iron-rich cavity, called the heme pocket.

Then the carbon monoxide waits until the protein's ever-shifting backbone untwists. "[The protein] needs to change its shape very drastically," Elber told Science News. "Hundreds of atoms move to the side." When the backbone's two helices nearest the heme pocket split apart, the small molecule can drift out.

Elber thinks molecules move into the protein along this same path.

"[The new work] is helping to clarify the mechanism of operation of this class of proteins," comments J. Andrew McCammon of the University of Houston.

In the past, scientists tended to simulate small molecules or much-simplified replicas of larger ones because computers lacked the computational power to keep track of all the atoms in a larger molecule. To complicate matters more, realistic simulations should deal with many molecules, each oriented differently in relation to the molecules with which they interact, Elber says.

"But with the steady increase in computing power and the development of more theoretical methods, people are beginning to look at very realistic biological molecules," says McCammon. "People are beginning to learn how these molecules actually work."

While at Harvard, Elber developed one method for avoiding the computational nightmare created by large molecules. Because the leghemoglobin dwarfs carbon monoxide, Elber's new program models just one leghemoglobin as hundreds of carbon monoxide molecules try to move around and through it.

These molecular pinballs then must maneuver through the protein pinball-machine. "The protein can move in so many different ways that there are going to be many ways that a [molecule] could go in," notes Elber. But only a few low-energy pathways exist, and his technique represents a promising way to determine those routes for carbon monoxide and other molecules, he adds.

"The molecular dynamics simulations offer a way of relating what is seen [in experiments] to the actual structure of the protein," says Gibson. "You can explain what is happening in terms of atoms." He and the Illinois duo have recently sought to harness simulations for designing new proteins.

As part of his research developing blood substitutes and understanding oxygen transport by heme proteins, biochemist John S. Olson at Rice University in Houston uses genetic engineering to make mutant forms of myoglobin. When Gibson used the Illinois model to study the dynamics of one mutant, the simulation indicated that the change would slow the movement of small molecules, which it did. This effort has prompted Elber to refine the model to make it more useful for biochemists seeking to redesign proteins, Olson says.

Another research group has already demonstrated the potential of this synergy between computational chemistry and molecular biology by making an enzyme that scavenges oxygen free radicals better than the natural version of that enzyme.

These enzymes work by attracting the negatively charged free radicals with a positively charged region.

To design the enzymes, researchers led by Elizabeth D. Getzoff, a structural biologist at the Scripps Research Institute in La Jolla, Calif., used computer modeling to examine how slight changes in the natural enzyme's amino acid sequence might alter the rate at which the free radicals enter the enzyme. The simulations suggested a change that focused the positive force field and guided free radicals more directly to binding sites in the enzyme, the group reports in the July 23 Nature. *— E. Pennisi*

Old idea may solve climate conundrum

If the past is truly the key to the future, then researchers interested in forecasting the expected greenhouse warming must understand how carbon dioxide gas participated in the geologically recent ice ages.

Climate experts have known for more than a decade that atmospheric concentrations of this heat-trapping gas fluctuated wildly from warm periods to cold ones. But scientists still lack a satisfactory theory to explain how levels of carbon dioxide could vary so drastically as the ice sheets waxed and waned. Two researchers are now dusting off a previously discarded idea that they say may solve this problem.

In 1980, bubbles of ancient air recovered from glacial ice taught scientists that the atmospheric concentration of carbon dioxide sank to 200 parts per million during the last ice age and then rose to roughly 280 parts per million after the ice age. The swings in the greenhouse gas are important because they help keep Earth in a deep freeze during glacial periods and help warm the climate between ice ages.

Bradley N. Opdyke and James C. G. Walker of the University of Michigan in Ann Arbor are now reviving a 10-year-old theory to explain the variations in carbon dioxide concentrations. This scenario focuses on the interplay between changing sea levels and the growth of calcium carbonate coral reefs on the continental shelves.

During glacial periods, the expansion of massive ice sheets on the continents pulled water from the ocean, lowering the global sea level. This process exposed carbonate reefs, causing them to erode through a chemical process that pulls carbon dioxide from the atmosphere and deposits it in the deep sea, according to the theory.

When the ice sheets melted at the end of the glacial period, sea levels rose and coral reefs regrew on the continental shelves. The growth of reefs released carbon dioxide into the sea water. From there, the gas escaped into the air.

Wolfgang H. Berger of the Scripps Institution of Oceanography in La Jolla, Calif., originally proposed the reef hypothesis in 1982. Yet he and other scientists thought this process could account for only a small fraction of the carbon dioxide changes between glacial and interglacial times.

In the August Geology, Opdyke and Walker suggest that reefs may play a much greater role than anyone realized. "What we're arguing is that this may be *the* dominant, first-order effect in terms of the historic carbon dioxide changes that we see over the last 100,000 years," says Opdyke.

Previous analyses missed the importance of the reef hypothesis because they underestimated the amount of carbonate currently being deposited on the continental shelves by coral, says Opdyke. He and Walker present evidence that reef growth is depositing double what others had assumed.

Plugging the new numbers into a simple model of the global carbon cycle, they found that reefs could raise and lower atmospheric concentrations of carbon dioxide by almost 80 parts per million — roughly the same spread as that seen in the air bubble record.

Berger says the reef hypothesis will probably not explain the full carbon dioxide changes. "There is a tendency to look for a silver bullet," he says. "We would all like to find one factor that does more than two-thirds of the job so that we don't have to worry about five factors. . . . My feeling is that it's not going to turn out to be one mechanism that explains it."

Other factors proposed to explain the carbon dioxide swings are increased growth of photosynthetic ocean plants and a reorganization of ocean currents.

— R. Monastersky