BRAINWORK

The Neuroscience Newsletter

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News FROM THE FRONTIER

••• Food Addiction Resembles Drug Addiction in the Brain

Dopamine is a neurotransmitter in the brain that, among other things, helps produce feelings of pleasure and satisfaction and plays a role in the addiction process of cocaine and alcohol. Researchers at the U.S. Department of Energy's Brookhaven National Laboratory have discovered that the brains of obese people have fewer dopamine receptors, suggesting that these people are compelled to overeat to stimulate the release of dopamine, in much the same way as addicts are driven to get high. The study results, published in the February 3 issue of *The Lancet*, could lead to new treatments for food addiction and weight regulation.

Gene-Jack Wang, lead author of the study, and colleagues measured the number of dopamine receptors in the brains of ten severely obese people and ten normal controls. Each volunteer subject received an injection of a radiotracer, a radioactive chemical that binds to dopamine receptors in the brain. Researchers then scanned the subjects' brains with a positron emission tomography (PET) camera,

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Inside:

Neuroscience at the Tip of the Ethical Iceberg

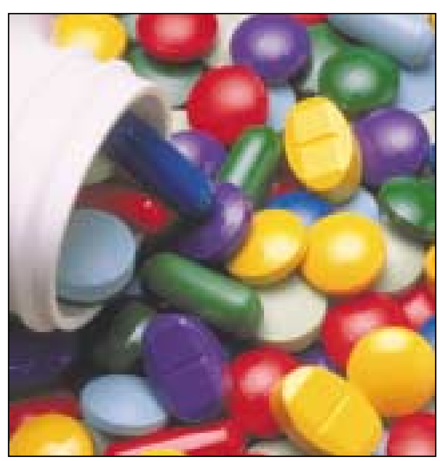
BY SANDRA J. ACKERMAN

If a little knowledge is a dangerous thing, a lot of knowledge may be even more dangerous—or at least more bewildering. Computer techniques for modeling complex objects (including the human body) and manipulating those models onscreen have added fuel to the debate over whether or when live animals are still necessary for medical research. The flood of genetic information has raised a host of new concerns, ranging from the privacy of medical records to ownership or licensing of the human genome. And in neuroscience, while the pace of research may seem agonizingly slow to people who are currently struggling with a brain disorder, it far outstrips the speed with which a diverse and busy society can absorb new knowledge about the brain and reach a consensus on how that knowledge should be used.

The Placebo

One of the liveliest debates on ethics in neuroscience today focuses not on new technology but on a long-established research practice. In American medical research, placebos provide the all-important "control" for a controlled study. One group of volunteers in such a study may be given a drug in the form of a pill, while another group is given an innocuous substance (such as sugar) in an identical-looking pill. The drug being tested must prove not just effective, but more effective than the mere process of taking a pill.

Passing this test is no small achievement: according to David Shore, Associate Director for Clinical Research at the National Institute of Mental Health (NIMH), the subtle psychological effect of receiving treatment—any treatment—can be very powerful, particularly in the case of a brain illness. In treatments of depression, for example, the "placebo effect" can account for 30 to 40 percent of the positive response rate. Shore explains the prevailing view among US researchers: "If the only scientifically valid way to show that a treatment works is to compare it to a placebo, then if you fail to compare it to a placebo you may be unsure whether the treatment is actually effective."



The use of placeboes in clinical trials has come under fire in many parts of the world.

Elsewhere in the world, however, the use of placebos is coming under fire as a technique that brings potential risk

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without benefit to the research subjects who receive them. In the Declaration of Helsinki, issued in October 2000, the World Medical Assembly proclaimed that placebos should be used only under very limited circumstances, when nothing else is available that can meet the scientific goals of the study.

Few scientists are claiming that placebos must always or must never be used. Sometimes a study can be designed to use an 'active control' (an already approved treatment) instead of a placebo, or it can have the control group start out using a placebo, with the option of switching to an active compound. Unfortunately, both these approaches run the risk of providing less-than-complete answers to the scientific questions under study. For example, new treatments for schizophrenia—a notoriously complex disorder—must of course be tested in subjects who have active symptoms of schizophrenia; often these are patients whose illness has proved resistant to most of the standard treatments. If such a study showed no significant difference between the results of a standard treatment and those of a prospective new one, this might mean that the new treatment was as effective as the standard one, or it might mean that neither of the two was particularly effective. Only by comparing active treatments to no treatment at all—that is, to a placebo—are scientists truly able to see what was or was not effective.

In any case, the use of placebos in American research will likely continue for some time. "The Declaration of Helsinki is a set of principles, not requirements," says Shore. Research in this country is governed by the 1991 Federal Policy for the Protection of Human Subjects, which does allow for the use of placebos under proper conditions.

Informed Consent

The tangle of questions surrounding 'informed consent' is closely related to the current argument over placebos. Researchers, reviewers, and the public generally agree that everyone who participates in scientific or medical studies should do so voluntarily and with an understanding of the possible benefits and risks involved. The procedure for obtaining informed consent may vary slightly from one research project to another, but always contains three main parts: answering questions about the aim of the research project, its risks, and the prospective benefits; confirming that the subject understands all the information; and insuring that the subject's consent is given freely and without coercion or undue influence.

As our knowledge of brain states and brain disorders has grown more sophisticated, terms like "voluntary" and "understanding" have become less easy to define. Can a person whose mind is weighed down with major depression make an adequate assessment of risks and benefits? What about someone who is distracted by the hallucinated voices of acute schizophrenia, or someone whose dementing illness robs her of short-term memory? If our very judgment is impaired by illness, can we truly give "voluntary" consent?

These ethical questions may haunt an investigator as he or she sets out to design a study, but in the end they cannot be resolved on a purely philosophical level; the study must include concrete measures to address them. Under the federal Common Rule, any biomedical study that seeks government funding must first be approved by the review board of its home institution (usually a university). The university, in turn, must regularly undergo review in order to maintain its standing with federal agencies. Thus, "there are various levels of oversight throughout the process," says Tryn Stimart, Human and Animal Subjects Advisor for the National Institute of Standards and Technology. "All this review takes a lot of time, but it's time very well spent."

According to Paul Appelbaum, professor and chairman of psychiatry at the University of Massachusetts Medical School, the capacity or incapacity to give informed consent is not a sharp distinction but a gradient—one that can shift over time even within individuals, depending on the course of their illness. "Merely knowing a person's diagnosis does not tell you whether he or she can take in complex information and form a judgment about it," he says. However, he continues, "it's not that many people have a true inability to understand the material, but that they have a harder time doing so." For such people, Appelbaum recommends that scientific studies include a new first step: educational intervention.

New Approaches to Old Goals

Taking extra time to educate prospective subjects about the purpose and goals of the study can significantly improve their understanding. The educational program may consist of group discussions, consultations with family members, and/or talks by peers who have taken part in research studies themselves. "These approaches are

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already being used in many studies, but not in a systematic way," says Appelbaum. The next step, he says, is to determine which approaches work best, and what proportion of people are effectively helped by them.

For patients and prospective research subjects who remain unable to give informed consent, the standard practice in this country is to rely on a legally appointed representative, most often a family member, to safeguard the individual's interests. But Appelbaum is concerned with people whose ability to give informed consent is likely to change over time, as with a neurodegenerative disorder (such as Parkinson's disease) or one that occurs in cycles (for example, bipolar disorder). For these people, he says, there is another option: the use of an "advance directive," in which the individual designates a trusted relative or friend to give informed consent on his behalf, should he himself become unable to do so. "Advance directives for treatment already are pretty well accepted," says Appelbaum, "but advance directives for research are still uncommon, largely because their legal status is still unclear in most states. We're going to be focusing on that as a public policy goal in the next several years."

While the scientific understanding of the brain continues to grow and options for treating brain disorders increase accordingly, the ethical questions now emerging still share some common ground with older debates. Most importantly, today's questions and earlier debates share a fundamental concern for the respect, dignity, and well-being of the human subject, wherever medical research is performed. In Stimart's words, "Whether in the United States or in Uganda, human subjects should all have the same rights and the same protection." The regulations, laws, and guidelines to protect people who participate in scientific and medical studies are far from perfect; but the sharpest tools for refining them may well be the rapid scientific advances that continually expose them to new questions. BW

Sandra J. Ackerman writes about science and medicine from Durham, North Carolina.

Embryonic Stem Cells Give Rise to Controversy

As if time-honored efforts to study and treat brain disorders did not raise enough questions, the prospects for the new, previously unimaginable stem-cell technology are stirring up even more. The human body produces stem cells throughout life as building materials for growth and development, normal replacement of worn-out cells, and the repair of injuries. These are immature cells that have not yet taken on a full identity; for instance, those produced in the bone marrow will develop into blood cells, and stem cells in the liver will mature into functional liver cells. But before birth, the stem cells of an embryo carry a kind of super-potential; they can develop into almost any kind of cell in the body.

The current ethical controversy centers on embryonic stem cells, those derived from a fertilized egg that once held the potential to develop into a human being. "A lot of experiments remain to be done to assess the usefulness of embryonic stem cells," says Tryn Stimart of the National Institute of Standards and Technology, "but ultimately they could play a role in some very important advances," such as providing new insulin-producing cells for patients with diabetes or replacing dying brain cells in a host of neurodegenerative diseases.

The ethical argument over embryonic stem cells has to do not with how they may be used, but with whether they should be used at all. Of those who oppose embryonic or fetal stem-cell use, some associate this work with abortion, others with an unacceptably utilitarian approach to human life. At the same time, proponents of the research say that the potential benefits of embryonic stem cells cannot be ignored.

While the ethical debate engages many of the best minds in the field, questions of supply and demand continue to speed stem-cell research in the private sector. In Stimart's view, "The work on stem-cell technology [and all its possible applications] is going to go on, but with a ban on federally funded studies that use embryonic stem cells, it will go on only in private companies." Such work may then be constrained by any number of patents, eventually becoming available for public use only by means of costly and time-consuming licensing. **—S.J.A.**

Anatomy of an Experiment:
Monkey-Robot Interface Offers Hope for Disease Applications

BY JOHN F. LAUERMAN

Late last year on a Tuesday morning at Duke University in North Carolina, a bearded, bespectacled neuroscientist named Miguel Nicolelis sat hunched over his laboratory telephone, talking with a colleague named Srinivasan Mandayam. At the time, he was more interested in what was happening 600 miles away in Mandayam's Massachusetts Institute of Technology lab than in his own.

"I was asking every second, 'Is it working? Is it moving?' Nicolelis recalls. "The moment he finally said 'Yes, it is moving, it is moving,' several people screamed in his lab and my lab, and I knew we had made history."

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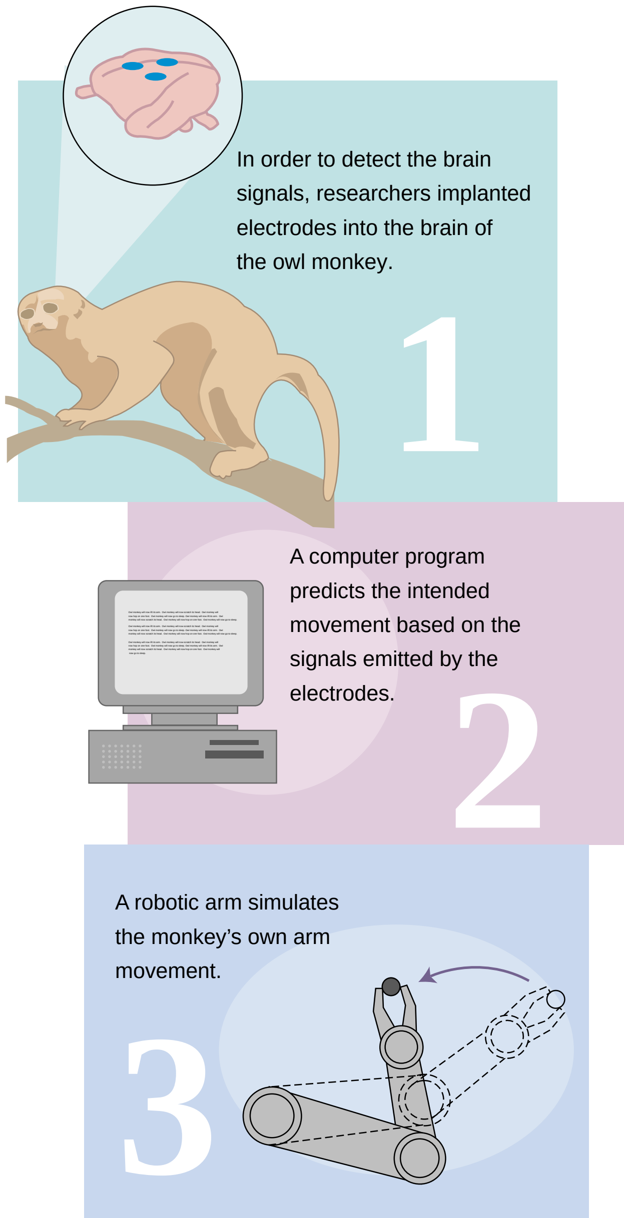
Dr. A.L. Nicolelis, the owl monkey and the robotic arm.

(ROBOT'S, continued from page 3)

The object of Nicolelis's interest was a robot arm directly connected to the brain of a monkey just a few feet away from him. As the arm in Cambridge, Massachusetts sprang to life, so did the hopes of enlisting robotic prostheses in the service of disabled people, although it may still be ten years until such devices are ready for use in humans, researchers say. Nevertheless, the culmination of years of research for the Brazilian-born Nicolelis, the experiment vividly demonstrated a growing understanding of how the brain designs and executes movements, a concept that could provide a new window on the brain's motor functions and on cognition itself.

The monkey-robot experiment, reported last November in the journal *Nature,* involved a scenario that until just a few years ago would have been considered the realm of science fiction: electrodes implanted in the brain of an owl monkey in Nicolelis's laboratory collected neural signals that were decoded and transmitted to remote sites at Duke and in Cambridge, Mass. There, the brain signals directed robot arms to mimic the movement of the monkey in Nicolelis's lab. The approach, Nicolelis's team believes, "could one day form the basis of a brain-machine interface for allowing paralyzed patients to control voluntarily the movements of prosthetic limbs."

What Nicolelis and his coworkers have done may someday be looked upon as a Rosetta stone in understanding how to harness the power of brain signals to guide machines. Using a technique developed with his mentor, neuroscientist John Chapin of State University of New York Health Science Center in Brooklyn, Nicolelis implanted tiny Teflon-coated microwires through which he and his colleagues can eavesdrop for up to two years on the brain's obscure language of electrical transmissions. Once the electrodes were in place, the monkeys learned to perform a variety of reaching tasks, for which they were rewarded after correct performances. Nicolelis and his team then began recording the neuronal signals in brain regions related to movement, or motor functions, trying to decipher which of them tell the arm and hand where to go.



Where is the best place to listen to the brain making plans for hand movements? In one monkey, Nicolelis's group implanted electrodes in different areas of the brain. They focused on the motor cortex, the brain region thought to be responsible for generating the commands to reach for objects. Yet it turned out that more easily decipherable results were obtained in another monkey whose electrodes were concentrated in the left dorsal premotor cortex, a brain region that some believe to be responsible for the timing and spatial features of the right arm's movements.

Classical observations indicate why these general patterns might contain usable information about movements. Movement researchers have long known that a person's signature looks roughly the same, whether the pen is held in the hand, teeth, or toes.

"The argument is that someplace in your brain, the idea of a signature is stored as a representation, a cognitive entity," says John Donoghue, chair of the Brown University department of neuroscience. "And it can be converted into a motor program, one that is independent of the muscles you have to use, whether they're in your fingers or your toes."

As much as it sounds like the topic for a Saturday afternoon matinee, Nicolelis's team found that divining the "idea" of arm movements from brain recordings turned out to be relatively simpler than expected. Johan Wessberg, a postdoctoral student in Nicolelis's lab, developed a computer program, or algorithm, that uses previous patterns of neuronal firing to predict what the next arm movement will be. The analysis took a fraction of a second, and the data were then sent to the robot arms at Duke and MIT.

"This simplified algorithm for extracting the relevant information was important for allowing them to activate the robots in real time," says Sandro Mussa-Ivaldi, an associate professor of physiology at Northwestern

University Medical School. "It was really much more of a technical achievement than a conceptual one."

Wessberg's economical approach pared down the size of the brain recordings to where they could be transmitted through the Internet to remote laboratories at Duke and MIT.

"Controlling the robot itself was not such a big challenge," says Mandayam, director of the MIT Laboratory for Human and Machine Haptics, also known as the Touch Lab. "The thing that was unknown was how to transmit across the 'net', and whether the time delays would cause problems, since packages of data arrive through the internet 1000 times per second, but with varying time delays."

Mandayam estimated that a delay of greater than 200 milliseconds would render the experiment a failure. As it turned out, the transmission protocol worked without a hitch.

"It was terrific," recalls Mandayam. "The motion of the robot itself was no different than if we had controlled it from right across the room. But the amazing part was that we knew it was being driven in real time from a monkey's brain signals 600 miles away."

"It was really one of the greatest days of my career as a scientist," Nicolelis says. "It was the realization of a dream."

How soon can the dream of brain-machine interfaces become a reality for people with paralytic or neurodegenerative conditions? Nicolelis is hard pressed to say.

"We want to be sure that we can obtain improvement in motor function that will be useful," he says. Currently, he is planning to work in new animal systems that offer more similarity to the human brain's convolutions, or sulci.

"It's exciting that we can do this, but we need to prove we can extract it safely with intracranial implants," he says. "Once we've done that, things can progress, but until then, clinical studies will have to wait." BW

John Lauerman writes about science and medicine from Brookline, Massachusetts.

The Mind's Eye:
Imagery and Visual Perception Share Common Brain Mechanism

BY BRENDA PATOINE

Look at the front page of this newsletter for a moment. Now close your eyes and create the image of the page in your mind. According to the findings of a recent study, it's highly likely that the same specialized subset of nerve cells in your brain was activated when you actually looked at the cover, and when you imagined how the cover looked.

The study, the first of its kind, sheds light on the still mysterious processes of imagery and visual recall, and how these relate to visual perception. Scientists have known for some time, based primarily on animal studies, that individual neurons in the brain are specialized for categories of images; for example, some are activated only when images of famous people are presented, some respond only to animals, some to food, etc. This helps ensure that the brain—and the organism—can respond to visual stimuli in the most efficient manner possible, firing up only those neurons essential to the recognition and processing of the specific object. The strategy makes sense from an evolutionary perspective: to survive, animals would need to respond instantly to stimuli that represented, for example, food or danger; having neurons dedicated to those stimuli would ensure swift response.

Scientists had suspected that the brain used a similar strategy to imagine or recall objects, again recruiting certain neurons for specific types of images. What was surprising in the new study, according to the investigators, was that, in many cases, the same neurons were activated when subjects actually saw the image as when they merely imagined it. "The brain machinery for generating either conscious percept based on an external stimulus (i.e., an image) and your memory of that image appears to overlap to a significant extent," says Christof Koch, one of the investigators at the California Institute of Technology.

Working in collaboration with neurosurgeon Itzhak Fried at the UCLA School of Medicine, who implanted microelectrodes into the brains of epileptic patients being evaluated for therapeutic surgery, scientists recorded the electrical activity of individual neurons. The technique had never before been applied to the scientific question of how the human brain

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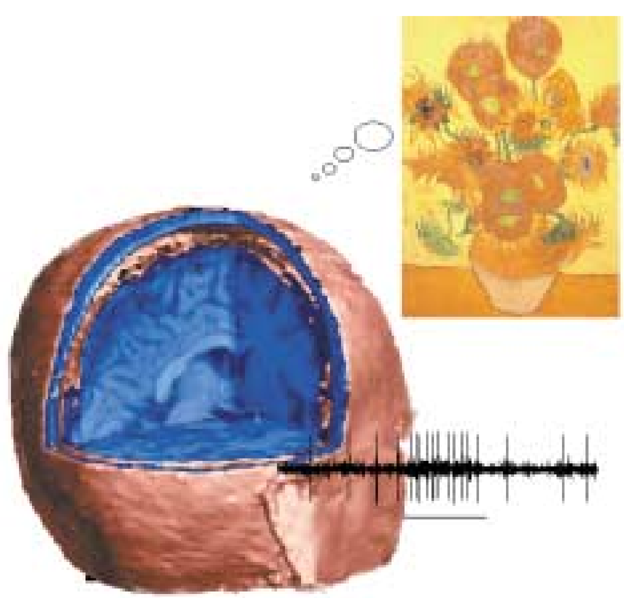

How many flowers are there in Van Gogh's "Sunflowers?" Subjects use visual imagery to estimate the answer with eyes closed, and specific neurons are activated during imagination. These same neurons are activated when looking at the picture as well.

(VISUAL PERCEPTION, continued from page 5)

forms the visual memory of an image vs. the visual perception of that image. The study subjects were people with pharmacologically-resistant epilepsy who were undergoing a clinical procedure to identify the focal point of their seizures in preparation for possible surgery; the scientific experiments were "piggy-backed" onto the clinically necessary procedure. With the electrodes in place, the subjects first viewed an image projected onto a computer monitor, then imagined the same object with their eyes closed, and the firing patterns of neurons activated during each task were tracked.

Surprisingly, of the neurons that were activated in both tasks, 88 percent had "identical selectivity," that is, the same neuron fired when the subject viewed an image of, for example, Bill Clinton, as when the subject visually recalled the image. As Koch explains it, "the very same neuronal apparatus is involved in forming the percept of Bill Clinton as in generating the image of Bill Clinton."

The fact that conscious recollection of a specific image activates the same neurons as visual perception of that image suggests an intriguing interplay among visual memory, imagery, and vision. The activated neurons were located in the medial temporal lobe, a part of the brain significantly involved with memory processes and other high-level brain functions. The processes by which the brain recalls memories are not well understood, despite decades of research, and this study contributes a significant new piece to the puzzle. "[It] suggests a common substrate for the processing of incoming visual information and visual recall," conclude the authors. Unexpected as it was, that conclusion helps advance scientific understanding of the "mind's eye" and opens the door to additional experiments that might further elucidate the neural mechanisms underlying visual recall. BW

Brenda E. Patoine writes about science and medicine from LaGrangeville, New York.

Dogged by Emotions

BY VICTORIA CONTIE

Man is the only animal that blushes—or needs to, wrote Mark Twain. But had Twain devoted himself to the observation of animals, he might have reached a different conclusion. How else to explain the strutting monkey's humiliated glances after he's fallen into a ditch, or a pet dog's shamed expression when he's not quite fully house-trained?

Behaviors and physical gestures like these, reminiscent of human emotions, are often detected by scientists known as ethologists, who study animal behavior. Likewise many pet owners can recount tales of apparent joy or jealousy exhibited by animal companions. But whether such behaviors are reliable indicators of underlying emotion in animals is a matter of debate. "There's no question that animals *have* emotions," says Marc Bekoff, professor of environmental, population, and organismic biology at the University of Colorado, Boulder. "It's more a question of: How we can study them?"

Bekoff is one of a growing number of investigators who are tackling such difficult questions. From more than 30 years of watching canines in the wild, Bekoff has concluded that these animals have internal experiences of emotion—in some cases possibly similar to our own—that can be discerned by observing their behaviors. Other ethologists have reported evidence of dolphins playing, or of elephants or sea lions steeped in grief. Famed primatologist Jane Goodall, for instance, once observed an 8-year-old chimpanzee who became despondent and stopped eating after the death of his mother. Within a few weeks, the previously healthy animal curled up in the vegetation where his mother's dead body had lain, and he drew his last breath. Other researchers have documented evidence of altruism in animals such as dolphins, which have reportedly rescued drowning swimmers or led lost boats to shore. Bekoff has collected many such personal accounts by ethologists in a book of essays called *The Smile of a Dolphin: Remarkable Accounts of Animal Emotions.*

Charles Darwin helped pave the way for this line of investigation when he proposed that emotions have a universal expression—a smile for happiness or a pout for sadness—that transcends human cultures and might even be shared among other species. But whether animals in fact experience emotions has long been controversial, and remains so today.

Part of the debate revolves around whether an animal must be self-aware to experience emotions. Higher primates, including humans, are the only creatures that exhibit indisputable signs of self-recognition, "but self-awareness is not a prerequisite to experiencing emotions," Bekoff insists. Patients with Alzheimer's disease or prelinguistic infants may not be self-aware, "yet no one would deny that they can have a strong emotional life," says Bekoff. "I think the same argument can be made with animals."

A pair of Atlantic spotted dolphins at play. Researchers are examining the emotional capacity of animals.

Most scientists agree that at least some animals experience the so-called primary emotions—including fear, anger, and surprise—that enhance an organism's chances of survival. The rapid physiological changes that accompany primary emotions prepare the body for immediate action, such as escaping a predator or fighting an intruder.

Of these emotions, the neural pathways underlying fear have been mapped out in the greatest detail. Fear conditioning in laboratory rats has confirmed that the small almond-shaped structure known as the amygdala, deep within the base of the brain, is the control center for processing dangerous stimuli and triggering body responses, such as a racing heart or an alarmed facial expression. When the amygdala is damaged—as in some humans who've had brain injury or surgery—individuals lose the ability to recognize fear in others or risky situations and can no longer respond appropriately.

But emotions other than fear are much more difficult to induce in laboratory animals, notes primatologist Richard Wrangham of Harvard University. "This is why field research—studies of animals in the wild or in free-ranging captivity—is indispensable." If animals do indeed experience joy or shame or compassion, Wrangham argues, then it makes sense to study these emotions in the complex settings for which they've evolved.

In The Wild

Indeed long-term field studies of social animals provide some of the most compelling evidence of a rich tapestry of emotions. Cynthia Moss, who has studied the social interactions of elephant families in Kenya for decades, has recorded countless cases of elephants lingering over dead relatives or tenderly stroking their skeletal remains. Maternal devotion is also evident. Moss once observed an elephant matriarch named Echo, who refused to abandon a newborn calf with deformed leg joints. Through a searing afternoon, with no food or water, Echo and her 9-year-old daughter struggled to help the baby

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recording the number of dopamine receptors based on the concentration levels of the radioactive chemical. The brains of obese subjects showed fewer dopamine receptors, and among the obese group, the number of receptors decreased in proportion to body mass. In other words, the more obese the subject, the fewer dopamine receptors.

Dr. Wang hypothesizes that the results offer numerous interpretations. "It's possible that obese people have fewer dopamine receptors because their brains are trying to compensate for having chronically high dopamine levels, which are triggered by chronic overeating," he says. "However, it's also possible that these people have low numbers of dopamine receptors to begin with, making them more vulnerable to addictive behaviors including compulsive food intake."

If a depletion of dopamine receptors is a cause of food addiction, treatments that regulate dopamine levels in the brain could help control the addiction. Also, since physical activity stimulates the release of dopamine as well, exercising instead of eating may control not only weight, but the compulsion to eat as well.

••• **Deaf-Blind can also Benefit from Cochlear Implants** Cochlear implants—devices that turn sounds into electrical impulses that are transmitted directly to the brain—are generally considered to be an aid to people who become deaf. The device allows the deaf user to differentiate sounds and learn to speak and read lips more easily. Now a University of Michigan Health System (UMHS) study proposes that the cochlear implant can allow patients who are not only deaf but also blind to regain significant ability to recognize speech. The report appeared in the January issue of the *Journal of Otology and Neurotology.*

The study, conducted by Hussam El-Kashlan, a cochlear implant surgeon and associate professor of otolaryngology (ear, nose and throat) and UMHS colleagues, examined patients who had already lost all or most of their hearing, and then began to lose their vision. The eight patients, all deaf and blind, received the cochlear implant and rehabilitation therapy, and took tests before and afterward to measure their ability to understand audible speech. Six of the patients received the implant as adults, and the other two were children who received the implant at age three and a half. All adult patients but one had developed language skills before going deaf, and neither of the two children had.

Before the cochlear implant, the five adult patients with previous language skills scored zero or extremely low on tests to measure ability to recognize sounds or words. After the implant and rehabilitation training, all five showed hearing test score improvement, and three of the five scored in the good to excellent range for audible recognition. The adult patient who had never learned to speak or understand words now has awareness of outside sounds, and is learning a limited vocabulary.

One of the child subjects went from a zero on sound recognition tests to a perfect score within a year after the implant. The child now scores well on sentence tests and attends a mainstream school. The second child has had numerous other unrelated medical problems, but displays an alertness and awareness of sounds.

El-Kashlan and his team believe that in deaf-blind individuals, the cochlear implant acts as a "sensory substitute," and the brain's ability to translate the electric impulses into recognizable sounds is an example of the plasticity of the brain: the ability to compensate and adapt to changes and handicaps. The team will next use medical imaging techniques to examine which areas of the brain are active when the deaf-blind subjects are exposed to different sounds.

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Cochlear implants work by bypassing the defective hair cells of the inner ear and directly stimulate the auditory nerve by use of an electrode. The device does not "cure" deafness; rather it allows the user to recognize some sounds and auditory cues in speech more easily, which in turn aids in communication skills. The FDA approved cochlear implants in adults in 1985, and in children as young as 2 in 1990. In Europe, children have received the implant as early as 8 months. Many scientists, El-Kashlan's team included, support the theory that the procedure has the greatest benefit in those who receive the implant early, when the young brain is in its critical period of development.

"News" is written by Andrew Cocke, Editorial Associate for the Dana Press.

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stand and walk toward a cooling mud hole. To Moss's surprise, the calf survived—largely because of his mother's unwavering devotion—and is now 10 years old.

Observations of marine mammals provide similar indicators of social bonding and emotion, says Toni Frohoff, a behavioral biologist and research director at TerraMar Research in Seattle. But studies of aquatic animals carry a unique set of obstacles, not the least of which is that dolphins appear to be perennially smiling, although the upturned curves of their mouths are not accurate gauges of happiness. Trying to understand dolphin emotions is "almost like trying to learn a new language with an unfamiliar alphabet," says Frohoff. "Dolphins live in the three-dimensional world of the ocean, very unlike our own, and their sensory systems are very different. They appear to rely on sound–especially sonar—more intensively than we do." But through persistent observations, Frohoff has identified individual- and context-dependent behaviors, such as specific tail flips or vocalizations, that seem to represent internal emotional states such as stress, frustration, or joy.

Although field studies are time-honored, their lack of controls can confound conclusions and make it difficult, if not impossible, to replicate and confirm research results. "The biggest challenge now is develop noninvasive techniques—imaging tools or other methods—that can ultimately be used on free-running animals" to provide quantitative measurements of emotional states, says Bekoff.

Victoria Contie writes about science and medicine from Rockville, Maryland.

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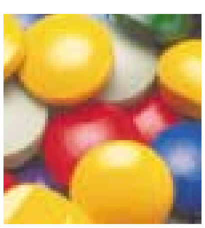

Neuroscience and Ethics