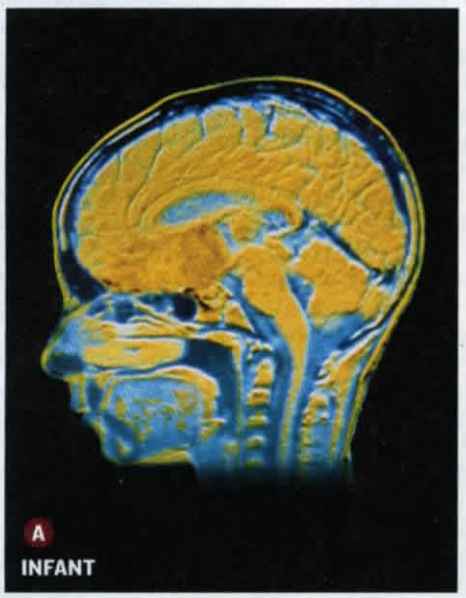
Glimpses of A Cosmic Creation

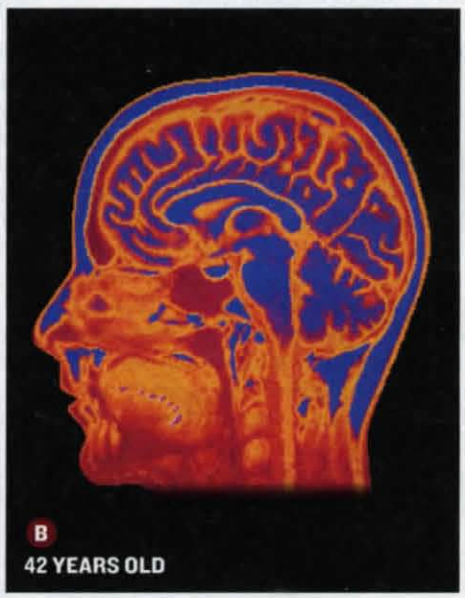
Talk about hubris. Surely the most outrageous notion in science is that observations, measurements and brainpower can divine the origins of the universe. Yet beginning in the 1960s, when astronomers detected radiation that permeates the cosmos and explained it as the whisper of a "big bang" that started the universe, they have done just that. "One of the most basic questions is where we come from and how we got here," says physicist Lawrence Krauss of Case Western Reserve University. "One of our greatest intellectual triumphs is realizing that the universe had a beginning."

It occurred 13.7 billion years ago, an explosion that created all matter and energy, plus space and time themselves. The universe expanded from a very hot, condensed "singularity"—the likes of which can be found today in black holes. Particles sped away on the expanding seas of space-time, coalescing into galaxies and stars; sometimes a star exploded, sprinkling the void with atoms that eventually formed our bodies. We are stardust. The cosmos continues expanding, its galaxies like dots on an inflating balloon.

When Does Your Brain Stop Making New Neurons?



A
INFANT



B
42 YEARS OLD

C
53 YEARS OLD

BY SHARON BEGLEY

THE SCIENTISTS ARE NOT SO NAIVE as to think they have discovered a magic wand that can turn animosity into compassion and hatred into benevolence, but the tarantula definitely raised their hopes. Over the years psychologists Phillip Shaver and Mario Mikulincer had uncovered more and more evidence that people's sense of emotional security shapes whether they become altruistic or selfish, tolerant or xenophobic, open or defensive. Once upon a time, that would have been that, for whatever their roots such traits were thought to be, by adulthood, as hard-wired as a computer's motherboard.

But with the new millennium scientists were finding that brain wiring can change, even in adults. That got Shaver, a professor at the University of California, Davis, and Mikulincer, at Israel's Bar-Ilan University, thinking: could they activate unused or dormant circuits to trigger the sense of emotional security that underlies compassion and benevolence? To find out, they gave volunteers overt or subliminal cues to activate brain circuitry encoding thoughts of someone who offered unconditional love and protection—a parent, a lover, God. The goal was to induce the feeling of security that makes it more likely someone will display, say, altruism and not selfishness. It worked. People became more willing to give blood and do volunteer work, and less hostile to ethnic groups different from their own. Offered a chance to inflict pain on an Israeli Arab with whom they were paired in an experiment (serving him painfully spicy hot sauce), Israeli Jews did not dole it out as they did without the security-circuit activation. They held back. And when they saw a young woman distraught over having to pick up a tarantula as part of an experiment, they volunteered to take her place.

ANSWER: NONE OF THE ABOVE

OK, so they didn't all sign up to work in Darfur. But as recently as a decade ago, proposing that an adult brain could be rewired for compassion—or anything else, for that matter—without experiencing a life-altering epiphany would have been career suicide for a neuroscientist. Not anymore. Experts are overthrowing the old dogma that, by the ripe old age of 3, the human brain is relatively fixed in form and function. Yes, new memories could form,

new skills could be mastered and wisdom could (in some) be gained. But the basic cartography of the adult brain was thought to be as immutable as the color of your eyes. This "neurological nihilism," as psychiatrist Norman Doidge calls it in his recent book, "The Brain That Changes Itself," "spread through our culture, even stunting our overall view of human nature. Since the brain could not change, human nature, which emerges from it, seemed necessarily fixed and unalterable as well."

But the dogma is wrong, the nihilism groundless. In the last few years neuroscientists have dismantled it pillar by pillar, with profound implications for our view of what it means to be human. "These discoveries change everything about how we should think of ourselves, who we are and how we get to be that way," says neuroscientist Michael Merzenich of the University of California, San Francisco. "We now know that the qualities that define us at one moment in time come from experiences that shape the physical and functional brain, and that continue to shape it as long as we live."

The brain remains a work in progress even on so basic a parameter as its allotment of neurons. For decades, scientists assumed that adding new neurons to this intricate machine could only spell trouble, like throwing a few extra wires into the guts of your iPod. But in 1998 Peter Eriksson of Sweden's Sahlgrenska University Hospital and colleagues discovered that brains well into their 60s and 70s undergo "neurogenesis." The new neurons appear in the hippocampus, the structure deep in the brain that takes thoughts and perceptions and turns them into durable memories. And studies in lab animals show that the new neurons slip into existing brain circuits as smoothly as the Beckhams onto the Hollywood A list.

Brain structure is also malleable, recording the footprints of our lives and thoughts. The amount of neural real estate devoted to a task, such as playing the violin, expands with use. And when an area of the brain is injured, as in a stroke, a different region—often on the mirror-image side—can take over its function. That overthrew the long-held view called "localizationism," which dates back to 1861, when French surgeon Paul Broca linked the

HELLO, DOLLY

Reproductive cloning creates animals that are genetically identical to an existing one. Since 1997, scientists have cloned 17 species:

SHEEP, 1997
Dolly makes headlines as the first clone of an adult mammal.

MOUSE, 1998
Researchers in Hawaii create 50 clones of a single mouse.

BULL, 1999
Cloning a bull leads to a debate about the safety of milk and meat from clones.

PIG, 2000
Five cloned piglets open the way to cloning animals to grow organs.

GOAT, 2000
The first goat clone dies from abnormal lung development.

GAUR, 2001
A wild ox becomes the first clone of an endangered species.

MOUFLON, 2001
A sheep becomes the first endangered-species clone to survive infancy.

RABBIT, 2002
Researchers clone a rabbit that may model human diseases.

CAT, 2002
A company formed to reproduce cherished pets clones the first cat.

MULE, 2003
Offspring of a horse and a donkey yield the first hybrid clone.

RAT, 2003
A challenge to researchers, its eggs begin dividing almost instantly.

AFRICAN WILDCAT, 2004
Researchers use a domestic cat as its own surrogate mother.

DOG, 2005
Researchers in South Korea clone an Afghan puppy they name Snuppy.

WATER BUFFALO, 2005
Cloned in China, it opens interest in improving the animal and its milk.

HORSE, 2005
It's the first clone whose surrogate mother is also a genetic donor.

FERRET, 2006
Researchers in Iowa hope to use it to study human respiratory diseases.

WOLF, 2007
South Korean scientists clone two gray wolves, an endangered species.

WHAT SHOULD WE ALL KNOW?

WHAT MAKES A PERSON CULTURALLY LITERATE? AS THE WORLD SEEMS TO GROW MORE COMPLEX BY THE DAY, THE QUESTION HAS TAKEN ON A SPECIAL URGENCY. CHECK OUT **EXTRA.NEWSWEEK.COM** FOR OUR TAKE ON OTHER SUBJECTS.

LEFT TO RIGHT, TOP TO BOTTOM: GETTY IMAGES, KIM TAYLOR—GETTY IMAGES, GEOFF BRIGHTLING—GETTY IMAGES, BILL LING—GETTY IMAGES, PETER ANDERSON—GETTY IMAGES, STAN OSOLINSKI—OXFORD SCIENTIFIC—JUPITER IMAGES, ROBERT MAIER—ANIMALS ANIMALS, GETTY IMAGES, DAVE KING—GETTY IMAGES, ANDY CRAWFORD—GETTY IMAGES, DAVE KING—GETTY IMAGES, JUPITER IMAGES, MIXA—GETTY IMAGES, PAUL A. SOUDERS—CORBIS, WILL & DENI MCINTYRE—PHOTO RESEARCHERS, GETTY IMAGES (2)

ability to speak to a spot in the left frontal lobe. But contrary to the belief that particular regions are unalterably wired for specific functions, even one as basic as the visual cortex can undergo a career switch. In people who lose their sight at a young age, the visual cortex processes touch or sound or language. Receiving no signals from the eyes, the visual cortex snaps out of its "waiting for Godot" funk and reactivates dormant wires, enabling it to perform a different job.

If something as fundamental as the visual cortex can shrug off its genetic destiny, it should come as little surprise that other brain circuits can, too. A circuit whose hyperactivity causes obsessive-compulsive disorder can be quieted with psychotherapy. Patterns of activity that underlie depression can be shifted when patients learn to think about their sad thoughts differently. Circuits too sluggish to perceive some speech sounds (staccato ones such as the sound of "d" or "p") can be trained to do so, helping kids overcome dyslexia. For these and other brain changes, change is always easier in youth, but the window of opportunity never slams shut.

From these successes, neuroscientists have extracted a powerful lesson. If they can identify what has gone wrong in the brain to cause, say, dyslexia,

Maternal care can affect an offspring's very DNA, turning on some genes and silencing others.

they might be able to straighten out aberrant wiring, quiet an overactive circuit or juice up a sluggish one. It won't happen overnight. But UCSF's Merzenich believes we have glimpsed only the surface of the ability of the brain to change. "The qualities that define a person have a neurological residence and are malleable," he says. "We know that in a psychopath, there is no activation of brain areas associated with empathy when he sees someone suffering. Can we change that? I don't know exactly how, but I believe we can. I believe that just as you can take a 17-year-old and put him through basic training, inuring him to violence, we can take a person who is insensitive and make him sensitive to others' pain. These things that define us, I'm convinced, can be altered." Only more research—and it's coming—will reveal how easily, and how much.

But what of the genes that shape our disposition and temperament? Here, too, malleability rules. As is often the case, this effect is easiest to detect in lab animals. Rats develop starkly different personalities depending on how they are reared. Specifically, if Mom is attentive and regularly licks and grooms them, they become well-adjusted little rodents, mellow and curious and non-neurotic mouse or rat. If Mom is neglectful, her pups grow up to be timid, jumpy and stressed out. Once, this was attributed to the powerful social effects of maternal

LINKS BETWEEN PAST AND PRESENT

Transitional fossils show the evolution of one group of organisms to another. Once called missing links, they have ancestral features of the older species as well as novel traits of the descendant. Among the scores of transitional fossils scientists have discovered:

375 MILLION YEARS AGO

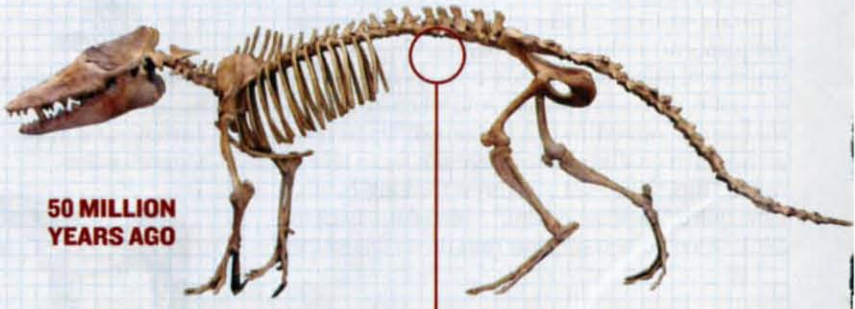
TIKTAALIK ROSEAE

This fish, unearthed on Canada's Ellesmere Island and reported in 2006, has fins like ancestral fish, but its pectoral fin contains arm bones like those in land-dwelling animals. With a bendable shoulder and elbow, plus a proto-wrist, the fin could support the body and propel it on land. Its ribs and limb bones resemble those of later four-legged amphibians and other terrestrial species.

150 MILLION YEARS AGO

ARCHAEOPTERYX

Discovered in Germany in 1861, this first bird retains such dinosaur traits as a long, bony tail and a full set of teeth. But it has birdlike wings and feathers. Its fingers are less fused and more open than in modern birds. Paleontologists have found nine fossils of the magpie-size creature, including one with a toe like a velociraptor's deadly claw.



50 MILLION YEARS AGO

PAKICETUS

A descendant of ancient whales and an ancestor of four-legged land mammals, the first Pakicetus was found in Pakistan in 1981. It could move on land but was also adapted for life in the seas, with paddlelike forelimbs, ears able to hear underwater and nostrils receding toward a blowhole position.

TOP TO BOTTOM: TED DAESCHLER—AFP-GETTY IMAGES, JAMES L. AMOS—PHOTO RESEARCHERS, J.G.M. THEWISSEN—NEOUCOM

care. But it turns out that Mom's ministrations can reach into the pups' very DNA. Maternal neglect silences genes for receptors in the pups' brains, with the result that they have few receptors and hence a hair-trigger stress response. Maternal care keeps these genes on, so the pups' brains have lots of receptors and a muted stress response. Inattentive moms also silence the genes for estrogen receptors in their daughters' brains; the females grow up to be less attentive mothers themselves. "It's almost Lamarckian," says Francis Champagne of Columbia University, referring to the discredited idea that offspring can pass along traits they acquire during life. "But experiences during a lifetime are passed on to the next generation."

Scientists are now beginning to see the first glimmerings of this in people, too. Very young children born with the form of a gene called 5-HTT associated with shyness usually are quiet and introverted. But by age 7, scientists led by Nathan Fox of the University of Maryland find, many are not. Only if the children have certain experiences—best guess: being raised by a stressed mother unable to provide emotional and physical protection—does the "shyness gene" live up to its billing. The molecular mechanism by which experiences reach down into the double helix and inhibit or elicit the expression of a gene is not as clear in people as it is in lab rats. At least, not yet. But it's an early sign that we are not necessarily slaves to the genes we inherit.

Few laypeople understand that neurological nihilism and genetic determinism have been so discredited. Most still embrace the idea that our fate is written in our DNA, through the intermediary of the brain wiring that DNA specifies. "It's puzzling that determinism is so attractive to so many people," says UCSF's Merzenich. "Maybe it's appealing to view yourself as a defined entity and your fate as determined. Maybe it's in our nature to accept our condition."

There is an irony to that. When people believe that their abilities and traits are fixed, interventions meant to improve academic performance or qualities such as resilience and openness to new experiences have little effect. "But if you tell people that their brain can change, it galvanizes them," says psychologist Carol Dweck of Stanford University, whose 2006 book "Mindsets" explores the power of belief to alter personality and other traits. "You see a rapid improvement in things like motivation and grades, or in resilience in the face of setbacks." None of that happens, or at least not as readily, in people who believe they are stuck with the brain they have.

This is not to say that everything will yield to the new brain science. There may turn out to be aspects of ourselves that resist every effort at change, for which we may be glad. But for too many decades, science sold the brain short. It is way too early in the battle against neuro-nihilism to declare anything beyond the reach of the brain's potential to transform itself. ■

How to Think Like a Scientist

Humans have 23 pairs of chromosomes containing about 20,000 genes, DNA is the molecule that carries hereditary information in every living cell, matter is made of atoms that are built of protons and neutrons and electrons and ... Alan Leshner isn't buying it. CEO of the American Association for the Advancement of Science, which publishes the journal Science and promotes science literacy, he agrees that people "need, at minimum, a rough understanding of the core concepts of science—the more the better." That would keep people from rejecting genetically modified food because, as they tell pollsters, it "contains genes" (all living cells do).

The real problem today, however, is not ignorance of the fact that Earth revolves around the sun once a year (something 25 percent of adult Americans do not know). "It's that people don't understand what is and isn't science," says Leshner.

Science observes and measures the natural world. From those data it infers the empirical laws that govern physical and biological processes. Explanations of large classes of phenomena must make testable predictions and be falsifiable. That is, there

must be a way to make an observation that could disprove the explanation. (Scientists call that overarching explanation a theory; the term does not mean, as it can in everyday parlance, somebody's off-the-cuff guess.) The requirement of falsifiability rules out supernatural explanations; you cannot disprove, for instance, the claim that God scattered fossils throughout rock strata to make it look as if species had evolved over millions of years. God may have done that, but we'll never know and there is no way to disprove it. In that way, faith is fundamentally different from science.

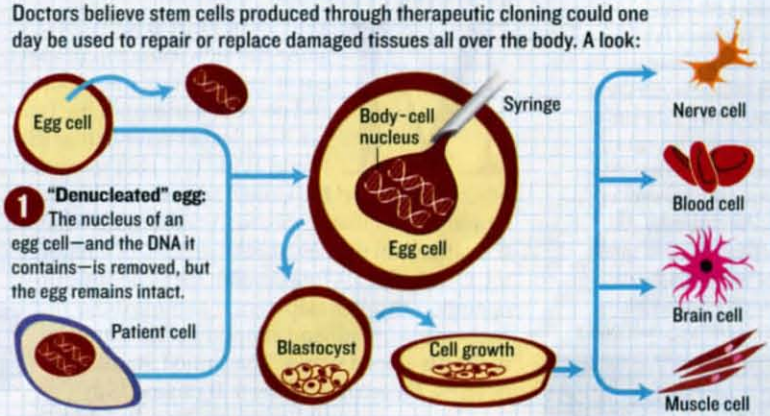
Despite the face it sometimes presents to the world, science is humble, recognizing that all findings are tentative (although in many fields the weight of evidence would be pretty tough to overturn) and only as good as the next experiment. It labors to distinguish true effects from random chance. Experiments have "control" groups to make sure that an effect thought to come from, say, taking a new drug does not also show up in people who did not take the drug.

Good science distinguishes correlation from causation. If kids who play violent videogames commit more violence, before you blame the game you'd better be sure that violence-prone kids are not more drawn to violent games than other kids. If so, then violent behavior causes the playing of violent videogames, and not the other way around.

-S.B.

THERAPEUTIC CLONING 101

Doctors believe stem cells produced through therapeutic cloning could one day be used to repair or replace damaged tissues all over the body. A look:



1 "Denucleated" egg: The nucleus of an egg cell—and the DNA it contains—is removed, but the egg remains intact.

2 DNA transfer: The nucleus of one of the patient's body cells, which holds the patient's genetic material, is transferred to the egg.

3 Cultivating stem cells: Chemicals are used to activate the egg, and soon a small cluster of cells called a blastocyst forms. Cells from this cluster give rise to embryonic stem cells.

4 Treatment: The stem cells could then be grown into any of numerous cell types and used to treat the patient.

SOURCE: WHITEHEAD INSTITUTE; GRAPHIC BY AMANDA YEZERSKI, TEXT AND RESEARCH BY MARC BAIN FOR NEWSWEEK

ILLUSTRATION BY HARRY CAMPBELL FOR NEWSWEEK