



SEARCH

Part of complete coverage on
CNN Ideas Series

Top brain scientist is 'philosopher at heart'

By Elizabeth Landau, CNN
updated 7:20 AM EDT, Sun March 31, 2013

SHARE THIS

- Print
- Email
- More sharing

Recommend 88



The minds behind the Brain Activity Map

STORY HIGHLIGHTS

Ed Boyden has won many awards for innovation in brain science

His tools could be used in mapping the brain

Optogenetics: Making neurons respond to light so that they can be manipulated

Boyden and Karl Deisseroth pioneered this technique

Cambridge, Massachusetts and Atlanta (CNN) -- Ed Boyden tilts his head downward, remaining still except for his eyes, which dart back and forth between blinks for a full 10 seconds. Then, as if coming up for air from the sea of knowledge, he takes a breath, lifts his head back up and begins to speak again.

During these contemplative moments, you have to wonder what's going on inside the head of this young scientist who, at age 33, has already helped invent influential technologies in the study of the human brain.

It made sense when he told me, on a cold February day in his office at the Massachusetts Institute of Technology, "I guess I was always a philosopher at heart as a kid."

The morning of our meeting, The [New York Times](#) had just reported the Obama administration is considering funding an initiative called the [Brain Activity Map project](#).

This is a [collaboration of researchers who are seeking tools](#) to map the human brain in unprecedented detail. A better understanding of how thoughts lead to actions, and how neural circuits lead to disease, could influence treatments for such conditions as epilepsy, autism, dementia, schizophrenia and even paralysis. Boyden is already working on such tools.

If you had to make a list of all

Clearly excited, Boyden bounces from his computer, where he's getting "zillions" of e-mails about the Brain Activity Map news, to the small table where we're speaking. In December, he participated in a

ADVERTISEMENT

Part of complete coverage on
CNN Ideas

Pick up your shovel; grow a better city

updated 5:59 PM EDT, Fri March 22, 2013



As a lifelong resident of South Central Los Angeles, I refuse to be part of the social system that breeds problems rather than solutions. South Central is a "food desert" where the lack of healthy food alternatives leads to obesity and preventable disease.

Exoskeleton allows paraplegics to walk

updated 6:13 PM EDT, Fri March 22, 2013



The idea of "wearable robots" may seem like something out of a movie, but this technology is already being used in real life.

One-handed violinist helps the disabled make music

updated 6:09 PM EDT, Fri March 22, 2013



The young man tucks his violin under his chin and begins to play. A hush falls over the few spectators in the largely empty opera house, who turn toward the bare stage. As his lilting notes float through the room, other people trickle in from the lobby to listen.

This 'Mousetrap' can crush a car -- and teach physics

updated 8:37 AM EDT, Wed October 10, 2012

the people in the world who are innovating in neuroscience, I think he'd be at the top of it.

Garrett Stanley, biomedical engineer

brainstorming session in Washington about the endeavor. After our meeting, he tells me, he'll lead a conference call with other researchers about next steps.

That was before the government's forced budget cuts, so it's unclear whether new federal money for brain research will come through anytime soon. But the Brain Activity Map proposal is mainly about innovative collaborations in neuroscience, which are taking place anyway. Boyden is a co-author of a [new paper in the journal ACS Nano](#), describing the value of nanotechnology tools in mapping the brain.

His efforts are being rewarded, as evidenced by the hodgepodge of awards in his office (as well as a certificate for "Mr. Most Likely To Be Late Because He is Teaching Students How to Build a Microscope"). In mid-March, Boyden won the €1 million [Grete Lundbeck European Brain Research Prize](#), shared with five other scientists, for his pioneering work in using light to manipulate the brain.

"If you had to make a list of all the people in the world who are innovating in neuroscience, I think he'd be at the top of it," said Garrett Stanley, associate professor of biomedical engineering at Georgia Institute of Technology.

Why we're making a map of the brain

Optogenetics: Lighting up the brain

When you electrically stimulate one part of the brain, a lot of nerve cells called neurons get hit at once. In order to understand what particular kinds of neurons do, there needs to be a way to target them separately. For this, Boyden and colleagues turned to nature.

"All over the tree of life, you can find organisms that use molecules to convert light into electricity for photosynthesis or photosensation," Boyden said.

One example is single-celled algae, which has a small eye spot -- a brown sphere -- that senses light, prompting hairlike structures called flagella to move and making the plant effectively swim.

What if you could take a small piece of DNA from the algae and transplant it into a neuron so the neuron now produces a light-sensitive protein (and installs it on the cell's surface)? Then, Boyden and colleagues reasoned, you would have a neuron that could be turned on or off with light.

As a graduate student at Stanford, Boyden would often get into late-night conversations with Dr. Karl Deisseroth, who was an M.D.-Ph.D. student at the time working in the same lab. Deisseroth and Boyden began exploring their common interest in how to control specific types of neurons in the brain. Together, they came up with the idea of inserting light-sensitive proteins in particular kinds of neurons.

It was August 4, 2004, around 1 a.m. when Boyden put a dish of cultured neurons under a microscope. The neurons were genetically altered with a light-sensitive protein called a channelrhodopsin. He shined a blue light at them. Amazingly, on the first try, the technique worked.

Boyden recalled that night of scientific discovery in an essay [published online by Faculty of 1000](#). He wrote: "I e-mailed Karl, 'Tired, but excited.' He e-mailed back, 'This is great!!!!'"

The data that Boyden collected that night demonstrated the ideas he and Deisseroth would later formalize in a 2005 *Nature Neuroscience* paper. Around that time, the term "optogenetics" was



If the crooked blue staircase, colorful crank and dangling bathtub looked familiar, well, that's the point.

Carpentry business creates hope for craftsmen down on their luck

updated 9:55 AM EDT, Wed October 3, 2012



Sometimes, it pays to eavesdrop on the next table over at lunch. That's how Brian Preston learned about the homeless people living in the woods around his suburban Georgia community.

A girl, the Internet, and her Pontiac Fiero

updated 11:43 AM EDT, Thu October 25, 2012



A couple years ago, Jerry DiMaria signed up for an online forum and started a new thread: "A few months ago," he wrote, "our 12 year old DAUGHTER came in and said, 'Dad, Mom, can we talk for a minute?'"

NewsPulse

Most popular stories right now

[Texas district attorney, wife killed](#)

[Behind the veil: Rare look at life in N Korea](#)

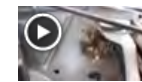
[U.S.: N. Korea threatens 'bellicose rhetoric'](#)

[1962's 'Playmate of the Year' dies](#)

[Trump seeks damages in 'cybersquatting' case](#)

[Explore the news with NewsPulse »](#)

More from CNN Video:



[Oil change leads to stuck cat recovery](#)



[The wedding seemed fine, but then ...](#)



[See what he does with passed-out girl](#)



[Why designer won't dress Michelle Obama](#)

More from CNN Health:



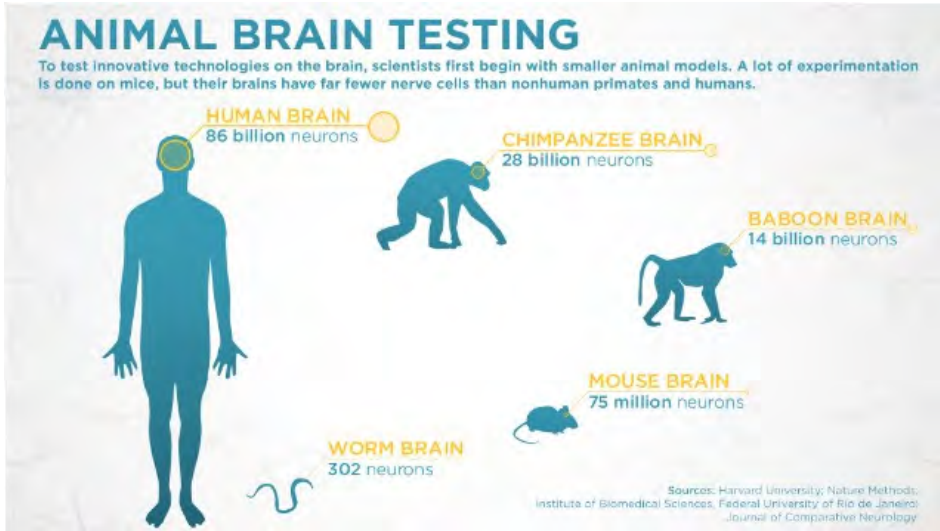
[5 things to do at the dentist's office](#)



[Couple's 500-pound weight loss just one success story](#)

born to describe what they were doing. Deisseroth is also a co-recipient of the recent European brain research prize.

Today, at least 1,000 neuroscience groups worldwide are using optogenetics to study the brain. The technique has so far been used in monkeys and mice to control their behavior, which has its own importance because it can yield new insights about the brain in general, Boyden said. Developing treatments for humans is another goal, but for reasons of ethics and complexity, that takes a lot longer.



ALBERTO MIER/CNN

What you can do with light

Being able to turn individual cells on and off could be powerful in finding therapies for brain disorders. For example, researchers could explore whether particular kinds of neurons are involved in the symptoms of schizophrenia, and selectively turn those off while leaving neurons essential for thinking intact.

This also has implications for treating addiction. In one experiment, scientists altered a mouse's brain so dopamine neurons -- involved in the sensation of pleasure, as well as addiction -- could be turned on with light. They delivered brief light pulses through optical fibers, prompting the mouse to stick its nose in a small portal over and over.

"An activation in these neurons lasting one-fifth of a second is enough to make the animal do more of whatever it was just doing," Boyden said.

Neurons can also be selectively silenced with light when they express other kinds of proteins. This is an avenue of exploration for treatments for epilepsy, a condition in which an excess in activity of neurons produces seizures.

Optogenetics may also prove crucial to creating a treatment for blindness; the idea is that you could make cells light-sensitive, converting the eye into a camera and restoring vision, Boyden said.

How to 'take over' a brain

"The tools he's developed are so broadly applicable," said Craig Forest, assistant professor at Georgia Institute of Technology. "Is it a stretch to say it's like the microscope for the brain?" He adds, "Optogenetics is the, kind of, microscope for neuroscience right now."

An accelerated career



Dentist's office a 'perfect storm' for HIV, hepatitis exposure,...



CDC: Second 'Tips' anti-smoking campaign

From Around the Web What's this?



11 Foods You Can't Buy Anywhere Anymore
The Fiscal Times



10 Early Signs of Multiple Sclerosis
Caring.com

ADVERTISEMENT

Health Resources from HealthGrades

[The best ways to beat depression](#)

[11 ways to avoid indoor mold](#)

[What is gluten sensitivity, anyway?](#)

[7 coping tips for chronic migraine](#)

[RA treatment: Aggressive is best](#)

The seeds of Boyden's career were planted in childhood. Growing up north of Dallas, he wanted to understand something about humanity and why we are here. He liked math better than science at first: "Math was the way of getting to the inner truth of things," he said. But then he wanted to know how our minds are able to understand math.

His thoughts gave way to an idea he now calls the "loop of understanding": Math is how we understand things at a deep level, our minds do math, the brain gives rise to our minds, biology governs our brains, chemistry implements biology, the principles of physics rule over chemistry, and physics run on math. It's a loop from math to math, with all the knowledge in between.

"I don't think I came up with that eloquent way to describe it until I actually came to MIT, but yeah, I was very interested in these kinds of things as a young teenager," he said.

His interest in science wasn't entirely a surprise; his mother has a master's in biochemistry, and conducted research on nicotine, but stayed home to take care of Boyden and his sister. His father was a management consultant (both parents are now retired).

"I was really a workaholic from age 10 onwards, I guess," he said.

Boyden remembers a statewide science fair in Texas when he was 12, where science-minded kids went to present their research.

It's hard to get him to talk about it now, but when I pressed him on the topic, he admitted, matter-of-factly, that he won the fair.

"Oh, you did! Do you remember what it was?" I asked of his project.

Boyden looked slightly uncomfortable, as if it were an embarrassing secret. "Uh, it was an area of geometry that has to do with the number of points on a plane and how they're connected and so on. It's not very easy to explain, nor frankly anything valuable."

However trivial his school-aged projects seem in retrospect, Boyden got to skip two grades. He enrolled at MIT when he was 16. On campus, he chose to live in a dormitory with a partying reputation. "I was very quiet, and so I went there to try and learn how to interact more with people," he said.



ELI REETH LINDORF/CNN

Ed Boyden leads the synthetic neurobiology group at MIT.

Making robots

Today, he seems to have no trouble in that regard. Said Forest, who works on technologies with him to study individual neurons, "Not

only is he just an incredible innovator, but he is just a really nice guy."

When Boyden arrived at Georgia Tech in February to give a lecture in the "Young Innovators" series, his puffy North Face jacket, slightly tousled curly locks and frizzy beard contrasted with Forest's pressed suit, lilac collared shirt and short salt-and-pepper hair -- almost like an Apple vs. PC commercial. The two communicate almost every day.

It's obvious how much respect Boyden has for his collaborators. Speaking to a standing-room-only lecture hall lined with dozens of students and faculty members, he spent the last minutes of his presentation reading off the names of students, post-doctoral fellows, collaborating groups and funding sources from a projected slide that listed even more of them. Then, he looked to the crowd and, almost in a whisper, said, "Thanks."

The idea that you could silence or activate neurons with light is a powerful one in combination with the tools that Boyden and Forest are working on together.

The two met at a social event at the MIT Museum while Forest was working on his Ph.D. at MIT. At that time, Forest was developing an instrument for genetic analysis involving thousands of glass tubes. Boyden told him about his own work in neuroscience, and about a problem that involved glass tubes for measuring neurons.

Forest didn't know anything about neuroscience, but he and colleagues "had a lot of expertise in how to build great devices," Boyden said.

The two researchers realized they could combine forces by creating a bundle of glass tubes, similar to what was being used for DNA analysis, for recording the electrical activity of individual neurons.

Neuroscientists often use mice, which have brains that structurally resemble those of humans, to test new technologies. Mice were the subjects of their first tests.

"We had no idea what we were doing at first," Forest said. "We went from a bundle back to one tube. We got that to work after three years of trial and error."

Those years paid off. Boyden and Forest, working with Forest's graduate student Suhasa Kodandaramaiah, developed a robotic system to record activity of a single neuron in the living brain using a tiny glass tube. The general technique, which has been around for about 30 years, is called "patch clamping," but this is the first time it has been fully automated through the assistance of a robot. The researchers have demonstrated the effectiveness of this technique in living mice, both awake and asleep.

Recording the neurons

Scientists know that the tube -- the "micropipette" -- has hit a neuron by measuring the electrical resistance between the tube and the brain. Resistance increases dramatically when the small needle bumps up against a neuron, as the tube forms a tight seal with the nerve cell.

"At that point, neuroscientists get very excited because you have the ability to hear the electrical activity of that single cell," Forest said. "Despite all the firing of millions of neurons in the neighborhood, once I form that seal, I can hear that one with exquisite sensitivity and precision."

There are only about a dozen of the automated patch-clamping robots in the world, but it's not Boyden and Forest's intention to

keep them a secret. On the contrary, they've posted the complete plans for the robot on the Internet so anyone can download them and create their own.

"I would argue, if you really understand how the mind computes your thoughts and emotions -- things like sharing credit, teaching and doing good for humanity become natural," Boyden said.

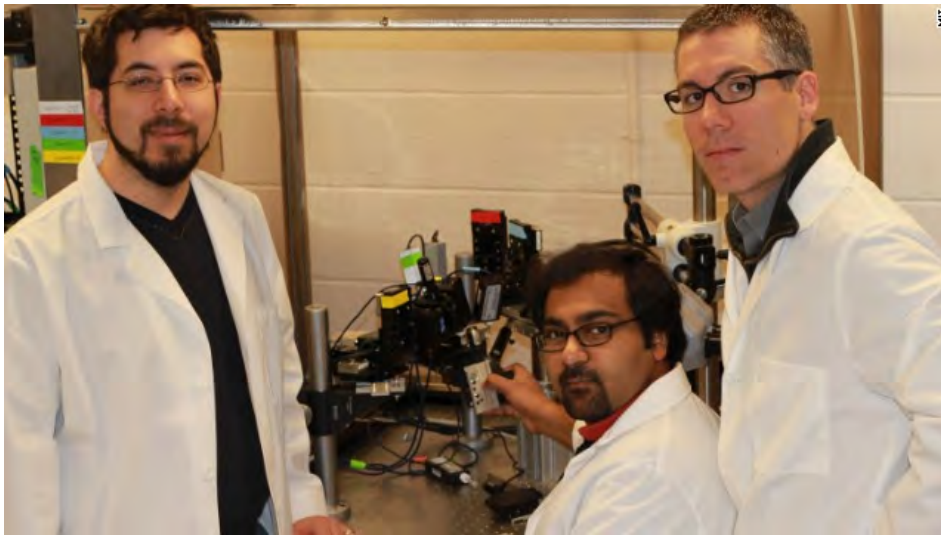
The researchers are also working on a scaled-down version that would cost less and be more portable. They have spun off an Atlanta-based start-up company called Neuromatic Devices to sell the finished products, but neither holds equity in it.

Optogenetics can be combined with automatic patch clamping to identify neurons of interest and then measure their activity. The robot could also perform single-cell surgery.

Forest's group has already used the robot idea to simultaneously record intracellular activity from more neurons than anyone else -- only three, surprisingly -- in a live mouse. The Brain Activity Map's ambitions involve intercellular recordings thousands to millions of neurons at once.

When compared that way, the current neural recording technology is like a steam engine, while we need a rocket ship, Forest said.

"We've got a lot of work to do, and our hope is that this just plants some initial seeds towards that endeavor," he said.



MIT researcher Ed Boyden (left), and Georgia Tech researchers Suhasa Kodandaramaiah (seated) and Craig Forest collaborated on a robotic system.

Other applications

One of the people e-mailing Boyden after The New York Times story was George Church, who has published research with him in the past. Church was one of the leading figures of the Human Genome Project, and a current backer of the Brain Activity Map.

Optogenetics, combined with high-density optical fiber arrays, could be a promising tool in the quest to map the brain, Church said. In other words, researchers can then use optic fibers to manipulate multiple neurons that activate in response to light. High-density optical fiber arrays would offer more, and thinner, probes for neuronal exploration than bulky electrodes.

Boyden and colleagues are also working on three-dimensional brain interfaces, manufactured in a way similar to computer chips. Rather than having computer circuitry on them, they have dense electrodes that would allow research to pick up on the activity of many neurons



Allan Jones: A map of the brain

at once.

The data from recording so many neurons will require a huge amount of computer storage; for recording the entire brain at once, it would be mind-boggling.

"Most of neuroscience has gone on with people studying one part of the brain at a time," said Georgia Tech's Stanley. "Here's somebody's lab over here that studies this part of the brain, there's somebody's over there that studies that part of the brain. Putting it all together is really a tough problem."

Controlling his own brain

People don't like to talk about enhancing the brain, Boyden said; it makes people uneasy to think about designing or engineering a way to sharpen our minds. Yet plenty of people take pharmaceuticals -- sometimes without a prescription -- to help themselves focus or be less anxious, and caffeine and alcohol have been around for centuries.

"I think the most important thing is for humanity to openly discuss this topic," he said. "If we can discuss it, and we also can talk about side effects, should we maybe try to design more optimized versions of things?"

Enhancing his own brain was something Boyden thought about long before he became a neuroscientist.

At 18, he was taking six courses per term, all graduate-level. Feeling overloaded, and also curious about what it would be like to take a drug that focuses the mind, he went to the campus psychiatrist and got a prescription for Ritalin. He doesn't remember anyone telling him to just take fewer classes.

The drug did make him focus, a lot. He took one pill when he woke up and another just before plasma physics class, "so I don't remember much from that term except for plasma physics," he said.

I think you really need to understand how your mind computes your thoughts.

Ed Boyden

But after a couple of months he stopped taking the Ritalin. He's not clear on whether the drug altered him permanently, or whether he just learned to focus better, skills for "how to simulate some of those processes in my mind."

Academically, Boyden never slowed down. On his 25-page resume, he lists perfect, or more-than-perfect, GPAs throughout high school, college and graduate school. At Stanford, he met his now-wife, neuroscientist Xue Han. They have published research together and are raising two young children. His "spare time" goes to his family.

In the last six years, he's found something new to calm himself and concentrate: meditation.

He meditates every day when he wakes up, incorporating a structure called "internal family systems," which involves looking at all the drives, thoughts and desires in your mind.

"By showing compassion for them, you can get them to become less polarized and work with them and negotiate between them and it's very powerful," Boyden said.

It takes him only a couple of minutes to get into a meditative state, which calms him and helps him analyze and address anxious thoughts.

I was surprised when he said he didn't know anything about the

neuroscience behind meditation, which is [a hot topic among other researchers](#), nor did he care about it as far as his own practice.

[How meditation may help your brain](#)

"I think that people should be careful about the need to see something in the brain to justify its worth," he said. "If you don't see anything in the brain, that might just mean the resolution of our brain (scans) just isn't good enough yet."

The future

You can tell Boyden thinks a lot, for his own curiosity, and his vibe is more "grad student"-like than professorial. His frizzy beard resembles the thin branch-like connections between neurons that he's talking about. Every time he runs his hand through his curly brown hair, it falls down in a different unkempt way.

He's thinking these days about what is needed to "solve" the brain, which he believes could be done in 40 years. "Solving" it would probably involve understanding what gives rise to a thought or an emotion, as well as maps of molecules and circuits that allow the design of therapeutic interventions. Building technology platforms that enable this kind of research -- so "we can repair the brain" -- is one of his core hopes.

Stanley isn't sure all that can happen in the next few decades, but he does envision that it's possible that, just as cancer can be a chronically managed disease, disorders of the nervous system may be able to go in that direction.

Forest chimes in: "There are prosthetics today, and those will continue to improve; these things exist in a rudimentary form today," he said. "Over our lifetimes, we will see increasing roles for technology in managing disease states."

Boyden admitted to enjoying the prominence of his work insofar as it makes more people invested in turning these ideas at the frontiers of brain science into reality.

"I think you really need to understand how your mind computes your thoughts," Boyden said. "I think that's incredibly important, so I like the fact that the prominence means the field and people entering it (and), you know, the world, want to make this happen."

Attention doesn't seem to be what's driving him. He's a man of many ideas, and wants to understand the biology behind where ideas come from.

"I guess I'm still drawn by the philosophy," he said.

10

[Comments »](#)

SHARE THIS

88

[Recommend](#)[Print](#)[Email](#)[More sharing](#)

From around the web

[Victim of \\$440K wire fraud can't blame bank for loss, judge rules](#) NetworkWorld

[Dangerous Signs of Depression](#) Lifescript.com

[Fun Fitness: Exercises That Don't Feel Like Work](#) Live Better America

[Kim Kardashian is Transformed in ELLE Photo Shoot](#) ELLE

[Plastic Surgery Disasters: Lil Kim, Meg Ryan & More](#) Hollyscoop

More from CNN

[Profile: Amanda Knox co-defendant Raffaele Sollecito](#)

[Katie Holmes nearly topless in new ad](#) 

[New York appeals soda-cup decision](#)

[First NBA player with MS takes the court](#)

['Obesity on the menu' for kids, group says](#)

[CDC: Second 'Tips' anti-smoking campaign](#)