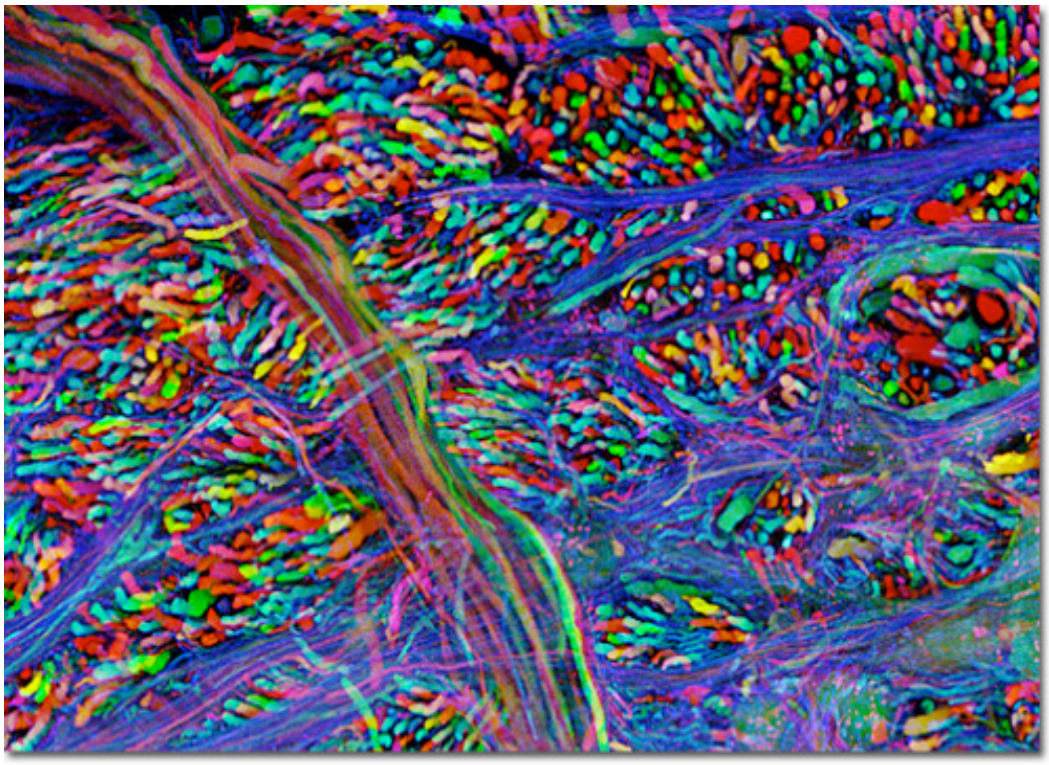
The Art of the Brain:

"Brainbow" and the Difficulty of Distinguishing Science and Art



A slice from the brainstem of a Brainbow transgenic mouse captured using a confocal microscope and software for image acquisition and manipulation. Credit: Jean Livet, Joshua Sanes, Jeff Lichtman. Harvard University.

By Ashley Taylor
Contributing Editor

When I start to ponder art, science, and what distinguishes them, I immediately think of a photo that I saw several years ago of a mouse brain whose individual neurons had been genetically engineered to fluoresce in one of around 100 aquatic-looking colors—violet, blue, chartreuse, ruby, yellow, and

everything in between. In a word, "Brainbow"; that is the name that biologist Jeffrey Lichtman and colleagues at Harvard gave the brilliant-brained mouse. In an image of the brain stem, the blue, violet, and green neuronal fibers form Van Gogh-like whorls; in snap-shots of the hippocampus, the cell bodies and their members, axons, look like a bunch of balloons floating up and dragging their strings. A Harvard press release described the images as "equal parts pointillism, fauvism, and abstract expressionism" in 2007, when the paper describing Brainbow was published in the journal *Nature*.

Though I would gladly put up Brainbow posters on my wall, I hesitated, at first, to call the images art; instead I placed them on the science side of a very fine, subjective line. Brainbow is a feat of genetic engineering meant to distinguish individual neurons in order to better understand the organization of the brain. The data happen to be beautiful. Are they art? Are they SciArt? And what, if anything, distinguishes art from science when their media overlap?

SciArt, when created by people who call themselves artists, seems rather straightforward. Artists use labs and scientific tools, microscopes and petri dishes, as ways of making work or creating art inspired by science. Yet scientists, who publish their work in scientific journals also make beautiful images. In these cases, as with Brainbow, the question is "Is there art in the science?" and that is harder; the fact that these images are produced by scientists in the course of work patently intended as science forces people to think about what art is beyond the easy (circular, unnuanced) answer of "anything made by an artist."

"Most people think science is a completely different realm from art, but I think that scientists who spend a lot of time making pictures get very confused about this." Lichtman, Harvard professor of molecular and cellular biology and head of the Brainbow project, tells me on the phone. "At least I do."

"Because these pictures are so... pleasing, I woudn't say artistic, but pleasing to the eye," Lichtman says, "I'm often confronted with this issue. Places like the Louvre in Paris, and other museums, have exhibits where they put pictures such as these in the exhibits to kind of force people to look at the beauty in nature and how scientific images can have beauty in them. You're kind of forced to confront this weird conflict between art and science, which, to most people, seems very straightforward—there's the world of art and there's the world of science—but when scientists use images to portray the world, especially to portray an aspect of the world that they think is important, we are doing something exactly the same as what artists are doing."

Though art is what fascinates me most in life, I have always respected science and been interested in it as a way of posing and answering questions. I majored in biology in college and now work as a science journalist. My concept of "answering questions" and my approach to doing it, by coming up with ideas and seeing how they hold up, are rooted in science. In the spirit of the scientific method, let's consider some hypotheses about what distinguishes art from science.

Hypothesis One: Science is done for a scientific purpose; art, for an artistic one.

I originally thought about Brainbow as science because it was created for a scientific purpose, not for art, and expected Lichtman to bolster that argument. In fact, Lichtman makes the argument that artistic and scientific purposes are equivalent.

"What is the purpose of art?" Lichtman begins. I fear the answer, knowing that his, like mine, like most, will be incomplete. "What is art?" is a question that, like "Does this dress make me look fat?" I instinctively avoid answering.

"The purpose of art," Lichtman goes on, "is so that people look at those images and learn something, about something... a lot of art, I think, has an impulse to display a point of view to teach an idea, to see the world in a different way; okay, how is that different? I see it as the same thing. Yes, I particularly am trying to understand something about how the brain works, and that's why we did this." Here, Lichtman points out the "scientific" purpose of his work, but goes on to say that "trying to understand something" is also what artists are doing. "To me, maybe because I've thought about it so long, I can no longer see the fundamental difference. I mean, I have a very particular issue in mind, but maybe certain kinds of artists are also focused on a particular idea that they want to get people to understand, and so their art is

about a particular thing." As Editor-in-Chief Julia Buntaine wrote in the inaugural issue of this magazine, art and science have a similar motivation: "an unquenchable thirst for understanding the nature of our existence."

Yet a common symptom of art is that an artist declares it to be so. The question of intention matters, and it complicated my view of Lichtman's work. Lichtman is a scientist, not an artist, and though the Brainbow images have appeared in museums, he did not set out to make Art. Lichtman's work was beautiful sort of by accident, as a byproduct of his scientific project. Art, on the other hand, looks as it does because artists plan it that way, doesn't it?

Or does it? Art, even visual art, goes beyond looks; often it's the artist's idea that makes a work of art, as is the case with conceptual art. I recently saw an exhibit at the MoMA of a white floor covered with yellow pollen that the artist had gathered from hazelnut trees in Germany over a period of years. "Pollen From Hazelnut," was impressive to look at, but a large part of the work's impact came from knowing that the artist, Wolfgang Laib, had created it by walking among the trees in his village, flicking the pollen off the branches into a coffee cup, and saving it in jars until he had enough for an installation. The work represented the ritual to gather the pollen, the feat of making something huge from seeds so small, the idea of years of life's work represented in a jar of yellow dust. If looks were what counted, the artist could have much more easily, I imagine, bought synthetic yellow powder to sprinkle on the floor. The pollen on display was a byproduct of the artist's way of life. Though that's not to say the pollen isn't important. In a 1986 interview in the *Journal of Contemporary Art*, (Laib has been collecting pollen for about 30 years.) Klaus Ottmann asks Laib, "What is more important for you, collecting of pollen or spreading it on the floor?" and Laib replies, "I think it's both. It's the pollen piece as a whole. But it's not as if I'm making an art out of the collecting. It's the pollen I'm interested in. For me the jar of pollen is as good as the spread-out piece."

Similar to the way that the pollen on the floor represents a larger concept, the Brainbow images are the result of the idea to label all the neurons in different colors. Perhaps they could be called conceptual art.

Conclusion: The distinction of purpose becomes blurry.

Hypothesis Two: Science uses a prescribed method. Art does not.

My ready answer to the question of what distinguishes art from science is that scientific data come from experiments, which in turn are designed according to the scientific method. The scientific method, taught to me in elementary school and reinforced throughout my scientific studies, is the following: you come up with an idea about how you think something works or what something does, a hypothesis; you design an experiment to test that hypothesis, in which you compare two cases differing only by that one factor, the variable; you and/or others then repeat to make sure the results hold up. I later realized, though, that this is not the entirety of the scientific method, as I'll soon explain.

Art, it seems to be, does not operate in this way. For one thing, it doesn't require an artist to repeat the same work many times before viewers will see truth in it. An artist can portray a unique situation—say, a worried mother in the Dust Bowl—with one iconic photograph, and people will interpret that photograph as a sign of the hardships of that time and place, without doing some kind of absurd test to make sure that the woman wasn't depressed even when well fed and comfortable. Dorothea Lange's "Migrant Mother" implies all sorts of things but doesn't prove them. A scientist could not draw conclusions from a single photograph the way people do from individual works of art. (For the record, Dorothea Lange took multiple photographs of Florence Owens Thompson and her children and who knows how many photos of other subjects beyond the one photograph that became famous.) Unlike science, art doesn't prove or explain things; art just documents the world and expresses views, ideas, beliefs.

Though there is no standardized "artistic method" analogous to the scientific method, I quickly realized that artists have methods, too (Stanislavski's being the obvious example), and some of them are science-y or, at any rate, mathematical. Dancer and choreographer Merce Cunningham was known for rolling a dice and, later, using a computer program to make decisions about his choreography. John Cage, Cunningham's partner and collaborator, also

used chance operations in composing music, and when the music and dance came together for the first time, often in the performance, the combination of dance and music was a matter of coincidence. The literary group Oulipo ("ouvroir de littérature potentielle" or workshop of potential literature) is a group of writers who create literature by using sets of constraints, often from mathematics. For example, Oulipo member Georges Perec built a novel, *Life A User's Manual*, on the basis of exploring an imaginary apartment block of 100 rooms, one room per chapter, with the order of rooms determined by a chess puzzle, the Knight's Tour. Perec also wrote a novel without using the letter *e*. The list could go on. Though I can't know, I imagine that most artists have some kind of method, routine, guiding principles.

Beyond the problem that artists have methods is the fact that not all science follows the method of hypothesis testing I described. In fact, Brainbow—a tool for observing the structure of the brain, a way to gather information—is not really part of a particular, hypothesis-driven experiment, at least not yet.
I bring up that point with Lichtman, expecting him to explain how Brainbow is, in fact, designed to test some hypothesis. That's not at all what he says. Hypothesis testing, otherwise known as deductive reasoning, is just one branch of the scientific method, he then reminds me. Inductive reasoning, he tells me, is another way of doing science and works in a very different way.

"Many of the great discoveries in science have come about through inductive reasoning, which is just the opposite. You don't start with a hypothesis. What you do is you start with observation, and then at the end of observing a lot of things, you formulate a hypothesis based on the observations. Once you have the hypothesis, then you can go ahead and do a deductive test of it, but you do this kind of data gathering, and during the data gathering, something occurs, some regularity appears that joins a lot of results together." Darwin's observations about related animal species, data from the Hubble Space Telescope, the sequence of the human genome, Lichtman says, are all examples of information gathering that led to the creation of hypotheses by induction.

"Brainbow definitely falls, at the moment, into the inductive side, where it reveals what is but does not explain why; it's not a hypothesis tester, it's a hypothesis generator." This quality of "showing without explaining" is just what I was trying to describe about the "Migrant Mother" photo.

Both kinds of reasoning, deductive and inductive, are very old, and people disagree about which type is superior, Lichtman adds. Philosopher Karl Popper, for example, argued against inductive reasoning in favor of coming up with hypotheses that, though they could never be proven to be absolutely true—an exception to a proposed rule might crop up in the future—could be proven false. Which brings me to my conclusion.

Conclusion: False because artists have methods and because not all science follows one prescribed method. Beyond hypothesis testing (deductive reasoning), inductive reasoning is a second method of doing science, and in its reliance on description and observation, it has much in common with art.

Hypothesis Three: Science simplifies things. Art renders their complexity.

Part of the thrill of going to a museum, one that has risen to the level of cliché, is staring at an image and wondering what it means, seeing new things in it. When you watch a play, you want the characters to remain somewhat unknowable; you want to go home still trying to figure them out. Looking at a Brainbow image as art, one might say that it represents the complexity of the brain.

Hypothesis testing focuses less on the world's holistic mystery, the great unknown, and rather, starts with what little is known and tries to increase that knowledge bit by incremental bit. In my experience, scientists get satisfaction out of knowing, with some degree of certainty, how something works, even if it's something very tiny. Individual experiments are rather simple by design: changing only one variable at a time to figure out what something does; comparing two mice that differ only by a single mutation, for example. True, few mice outside the lab, barring some identical twins, differ by only one mutation, and what we know about mice is certainly an approximation of the way human biology works—yet it is one of the best approximations we have and one very well suited

to scientific experiments.

I am often taken aback when people opine that an explanation is "cartoonish," usually in social or political contexts, that it's too simple. Explanations are supposed to be simple, the biologist in me wants to retort. I think back to the scientific papers I've read, the undergrad thesis I wrote, which along with graphs and photographs of data included little computer graphics, in black boxes, explaining how the experiments work or describing a cascade of molecular signals, with the molecules represented by little ovals and squares. These diagrams are meant to be cartoonish and, on some level, so are experiments: despite the world's messiness, they are supposed to be simple and explainable, a neat corner to take stock in.

Scientists looking at Brainbow see it as a tool for breaking the complexity of the brain down into tiny, incremental chunks, right? Actually, not really. Lichtman, too, thinks the Brainbow images represent the complexity of the brain and that capturing that complexity is important. "I am personally much more enthralled with description than experiment, so we do experiments rather sparingly in my lab, and the reason for that is that the brain is extraordinarily complicated, and while one can generate hypotheses, they always seem, to me, to be somewhat not up to the task of describing the extraordinary complexity of the brain."

Conclusion: False because science can appreciate complexity, too.

Hypothesis Four: In science, there is some notion of right and wrong. Art is just art.

One of my ingrained ideas about what distinguishes art and science is that in science, there really are, if not right answers, at least wrong answers. The idea of doing experiments and making hypotheses and deductive reasoning is founded on the assumption that it's possible to know things absolutely and say that certain things are not true, that others are very likely to be true. Though there are debates in science, they are debates over experiments and what the experiments prove or don't prove. Though there's uncertainty associated with all results, uncertainty in science is something that statistics has quantified, not just a feeling of doubt. In science, people respect experiments as ways of getting information.

Science seems to be one of the few places where absolute judgments hold sway. Outside science, everything is up for debate, particularly in the digital age, when so-called facts are readily available to argue for both sides of any question and people decide what they believe based on factors that may or may not include the relevant experiments.

The words "right and wrong" just don't fit in the realm of art. They seem like foreign concepts. When I think about art, I turn away from logic and toward association; I use instinct and feeling more than reasoning. This is one hypothesis that may have some truth in it: In art, there is no right and wrong; In science, there is, well, *wrong*.

Despite my respect for experiments, I start to believe that in trying to understand something about art and science, hypothesis making is not the best approach. My deductive reasoning left me with a bunch of wrong answers, and while that's nice, concrete information and all, it's not particularly satisfying. I start to feel, as Lichtman does about the brain, that this is a subject that hypotheses, at least mine, are not up to the task of explaining.

I first contacted Lichtman specifically to ask how he chose the colors for Brainbow. I knew, from some research about microscopy, that in some cases, the colors you see are arbitrarily assigned to particular wavelengths of fluorescence that the microscope detects. They aren't simply photographs of the fluorescence itself. It seemed to me that using false colors would tip the scales toward art. **My unspoken hypothesis: Science (always) deals with reality. Art does not (always).**

Lichtman's response was that my questions were not straightforward and suggested that we talk on the phone. The problem with that question is that all colors are false, in a way: they are assigned by the brain.

Lichtman explains that, the microscope he used to photograph samples from Brainbow neuronal tissue detects three wavelengths of light, or ranges of wavelengths, representing three colors: green, red, and blue. Based on the relative intensities of the three wavelengths, a color is assigned to a particular pixel of the image. That might sound artificial, and maybe it

is, in a way. It's not, however, unnatural: it's the way the human eye perceives color. In the eye, there are three kinds of cone photoreceptors for detecting color: one that responds most strongly to green light, one to red light, one to blue light. The hue we see depends on the relative stimulation of the three different photoreceptor types.

I sense Lichtman trying to describe what the sample is "really" like and contrast it to what he sees under the microscope: "Other than actually looking at the sample... Even looking at the sample, you're looking at it with an eye that has three photoreceptors, only three filters, a red filter, a green filter, and a blue filter. In all cases—this is not the difference between art and science—the colors are a human rendering of what the colors are... It's important to realize that in all forms of art and science, even in our own brains, when we look at things, we're never actually seeing what is really there; we're filtering it through a series of steps."

Then he says something that makes it clear why, fundamentally, the distinction between art and science is so difficult. It deals with the nature of reality. Despite all the exceptions, and the imagination required to come up with hypotheses about the unknown, we think of science as being grounded in reality. Despite photography and other reality-based forms, we associate art with creativity and the imagination. But every image we see is presented to us by our brains. It's all some degree of imagination.

"The dirty secret about color is that color is completely manufactured by the brain. Light has energy... but there's nothing intrinsically colorful about those energies. We have these photoreceptors in our eyes that are activated by particular wavelengths, but the light itself... Color is a construct of the human mind." This is a "dirty secret" about not just color but all of reality. I spend so much of my time thinking about how artists reconstruct, portray, and evoke reality, but neuroscience tells us that reality, itself, is reconstructed, portrayed, evoked by the brain. It is the art of perception.

(opposing page, from top left to bottom right)

All images courtesy of the artist.

(1) Washed Away (2013). 24" x 24". Grown from a tear. Scanography, printed on brushed aluminum.
(2) The View (2011). 15" x 15". Grown from a sea shell. Scanography, printed on white aluminum.
(3) Fish Wave (2011). 15" x 15". Grown from a fish scale. Scanograpy, printed on brushed aluminum.
(4) On the Tip of the Tounge (2013). 20" x 20". Grown from saliva. Scanography, printed on white aluminum.
(5) Parmesan Eye (2011). 16" x 16". Grown from Parmesan cheese. Scanography, printed on brushed aluminum.
(6) Binary System (2013). 20" x 20". Grown from a belly button. Scanography, printed on white aluminum.
(7) Where Stars Come From (2013). 24" x 24". Grown from a belly button. Scanography, printed on white aluminum.
(8) Aquatic Sun (2013). 16" x 16". Grown from a black algea. Scanography, printed on brushed aluminum.
(9) Black Hole (2013). 30" x 30". Grown from a belly button. Scanography, printed on white aluminum.