Human Brains

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And now, I'm going to talk about human brains. The brain is the organ in our head that we think we think with.

Unfortunately, brain science is changing, so I'm going to go out on a limb here and discuss science that in some cases is less than a decade old, which means some of what I say will probably be demonstrated to be wrong in the future.

As well, while technically I am a doctor, since we are talking about brains and not sick pebble bed nuclear reactors, I am going by what I have read and my personal experience as a brain owner.

Most of the information processing in us humans happens in our skull, but there is processing from our senses and other miscellaneous things like helping muscles move that happens outside the skull. So in my brain, I think of something to do, and the brain plans the movements and sends the impulses to the correct nerves, which eventually move muscles. I will now, with the power of my mind, move matter: (lift up arm, as if by a string.)

Inside your brain you have about one hundred billion neurons.[1] The CPU[2] of the computer I created this sermon on has about 80 times fewer transistors than our brains have neurons. Neurons are sorta combination wires and transistors and short term memory in the brain. Their function depends on how they are hooked up and what molecules are on the surface. Humans know roughly how neurons work. We can put electrodes in both ends of a neuron and watch the electrical signal propagate. We can put electrodes in two different neutrons and watch the signal get amplified or suppressed.

Once you join together hundreds of neurons we don't understand how brains work. We don't even understand how C. elegans', roundworms', brains work. The male C. elegans' have 383 neurons and the hermaphrodites have 302 neurons.[3] Humans have mapped the neuron connections in C. elegans, but we still can't figure out how it fully works well enough to simulate it in a computer.[4]

At least we roughly know what neurons are doing. We are still trying to figure out exactly what glial cells in the brain do. There are a lot more glial cells than neurons. For every neuron, there are 10 to 50 glial cells.[5] One thing we do know that some glial cells do is form myelin sheaths around neurons.

Myelin acts as insulation and speeds transmission along neurons.[6] If you lose myelin in your brain and spinal cord you get multiple sclerosis. If you lose myelin in your limbs, you get GuillainBarré syndrome, and you have weakness in the feet and hands. And if you lack myelin in the front of your brain, in places where you do things like set goals and weigh different agendas, you are a teenager.[7]

There is a reason for that last one. Once the neu-

[1] "on the order of 10^{11} neurons." Principles of Neural Science (PONS), edited by Eric Kandel, James Schwartz and Thomas Jessell (Jan 5, 2000), ISBN: 978-0838577011, pg 19

[2] A Intel Core i5-4200M with 1.3 billion transistors

[3] `http://www.wormatlas.org/male/introduction/mainframe.htm` Introduction to Male C. elegans Anatomy, Lints, R. and Hall, D.H. 2009.

[4] `http://www.nytimes.com/2011/06/21/science/21brain.html` In Tiny Worm, Unlocking Secrets of the Brain, By Nicholas Wade, Published: June 20, 2011 (Part of the complication in simulating C. elegans' neurons is the gap junction chemicals are still being figured out.)

[5] PONS, pg 20

[6] PONS, pg 85

[7] `http://ngm.nationalgeographic.com/2011/10/teenage-brains/dobbs-text/2` David Dobbs, Teenage Brains, Oct 2011

rons are covered with myelin, it is much harder to create new connections between different neurons. So in teenagers, evolution has made them quick learners at the expense of being quick thinkers.

Evolution has shaped the brain. Parts of our brain such as our emotions are shared with all mammals. Humans have the same basic emotions as rats. These include searching or curiosity, fear, rage, lust, nurturing, grief and play.[8] As Panksepp and Biven write:

"[A]t the primary-process level, emotions are not a matter of individual learning. They are built into the brain by evolution: They are ancestral 'memories.' To the best of our knowledge, we are born with innate neural capacities for the full complement of seven basic emotions that are hardwired into the subcortical networks of all mammalian brains. We see this clearly in studies of animals that use techniques such as localized stimulation of specific brain regions. For example, if one provides artificial arousal in the form of electrical or chemical stimulation to the system that generates FEAR, (...) even young, inexperienced animals will cower."[9] wrote Panksepp and Biven.

If you stimulate the medial areas of the amygdala in rats by putting an electrode there, they start biting other rats or mice.[10] If you stimulate that area in cats, they start hissing and growling.[11] If you stimulate the medial areas of the amygdala in humans, they clench their jaws and have intense feelings of anger.[12]

Of course, humans are not rats, we have more rational parts of our brains over these basic levels. It is easy to do claustrophobia studies in a functional magnetic resonance imaging machine, but it is hard to do anger studies[13] since angry people don't want to stay inside a confined space, but from studies in functional magnetic resonance machines it seems that anger is correlated with higher cortical regions shutting down. So either strong anger shuts down our more rational thinking, or stopping our more rational thinking allows strong anger.

The interaction between the different parts of the brain and the body is not perfect. For example, I have definitely had my brain tell me I really wanted a piece of cheesecake, only to have my same brain tell me five minutes later after eating the cheesecake, you didn't want to do that. Our brains contain different goals, some working at quite different levels, that don't always work together well.

Memory also doesn't work as well as we would like. As Gary Marcus, a research psychologist states:

"All memories – even those concerning our *own* history – are constantly being revised. Every time we access a memory it becomes "labile," subject to change, and this seems to be true even for memories that seem especially important and firmly established, such those of political events or our own experiences. [14] says Marcus.

Two researchers, Talarico and Rubin, asked students on September 12, 2001 to write down what they were doing when they first heard about the September 11th attacks. Then weeks and months later they asked them again and the researchers compared the answers. As time went by, the students' answers contradicted their previous answers written the day after, but still believed they remembered September 11th correctly.[15]

It's not that surprising that memory has problems. When I was reading the details of how memory chemically works, I was struck by the needlessly complicatedness of it. For example, let my try to explain how the Cyclic AMP pathway that is used for both short term and long term memory works.

It starts when two neurons are in contact and one releases transmitters to stimulate the other neuron. The stimulation allows the receptor to expose a site that then waits until a stimulatory G protein wanders along the surface of the cell and binds and turns the G protein into an activated stimulatory G protein. Later GTP can migrate in the fluid in the cell and

[8] Archaeology, pg xi

[9] The Archaeology of Mind: Neuroevolutionary Origins of Human Emotions (Archaeology), by Jaak Panksepp and Lucy Biven, 2012, ISBN: 978-0393705317, pg 20

[10] Archeology, pg 166

[11] Archeology, pg 165, 153

[12] Archeology, pg 150

[13] Archeology, pg 160

[14] Kludge: The Haphazard Evolution of the Human Mind, pg 30, Gary Marcus, 2009, ISBN: 978-0547238241

[15] Confidence, not consistency, characterizes flashbulb memories., Jennifer M Talarico, David C Rubin, DOI:10.1111/1467-9280.02453

switch with the GDP on the stimulatory G protein and split the G protein into an alpha subunit and a beta-gamma part. The alpha subunit wanders on the surface of the cell until it runs into a cyclase enzyme. This enzyme converts ATP to cAMP.[16] The cAMP molecule then wanders in the cell and can lead to both short and long term memory.[17] If you remember this sermon, then right now in your brain this chemical pathway is taking place. It's a Rube Goldberg mechanism, and to me at least it seems that you could eliminate a lot of levels, except that if you remove a step, it doesn't work, and so all the steps are still around, kept by evolution.

As humans have figured out more of the workings of the human brain, we are approaching the point where we can simulate an entire human brain on a computer. Simulating a full brain would however take a supercomputer and mapping out the neurons. If we succeed, I don't think it would be ethical to turn the computer simulation off because it would be a thinking human.

So soon, computers will be able to simulate human brains. However, in the other direction, computers have now become so fast that humans cannot reasonably simulate the workings of a computer by hand. I estimate it would probably take over two months for me to figure out what the computer chips in a 1982 Commodore 64 would run in a second.[18]

Because of the complexity, humans have not yet simulated a human brain on a computer. However, there are plenty of other things that would have been science fiction recently that humans have figured out. These include things like controlling a beetle's flight with electrodes[19] and using a monkey's brain to directly control a robot arm[20]

For the beetle flight control, the researchers put one or two electrodes into the beetle's brain, and then tried different pulses of electricity. They discovered they could make the beetles fly, stop flying and change the direction of flight. I found it fascinating that this is possible, but really creepy at the same time. Neurons in humans aren't that different from neurons in a beetle, and so it is worth remembering that if it can be done with beetles, it is possible to do with humans.

In a closer to home example, human and other monkey brains run the neurons that think about moving muscles close to the surface of the brain. Humans have put arrays of electrodes into monkey brains, and then attached the output to a robot arm. Over time, the monkeys learned how to send the right signals in their brain to move the robot arm. Scientist have also been able to do this with humans to allow people who are paralyzed to be able to do things for themselves. One woman who was paralyzed from the neck down was able to feed herself.[21] This sounds quite useful to me. Despite its similarity to the beetle experiments, I'm not creeped out by it. Rationally I realize that the knowledge required to both types of experiments is very similar, it is just the direction of the signals, are they going from the brain to the computer or from the computer to the brain.

I've been working on this sermon on and off, mostly off, since October of 2013. One piece of advice I heard during this time was to speak from the heart. Anatomically, this is not quite correct, since your heart doesn't really have the right kind of nerves to be generating emotions. People who have had the misfortune of a spinal cord break still feel emotions, even tho' they can't control or feel parts of their body.[22] The part of our brains that has the emotions is a lot closer to being directly between our ears, where the spinal cord meets the rest of our brains.

But, the deeper meaning to speaking from the heart touches on what it means to have a human kind

[16] PONS, pg 231-234

[17] PONS, 1250

[18] 60 seconds to simulate one 'operation' and maybe 100,000 operations per second. 1e5*60/3600.0/24 = 69 days

[19] published: 05 October 2009 doi: 10.3389/neuro.07.024.2009 Remote radio control of insect flight `http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2821177/pdf/fnint-03-024.pdf`

[20] `http://www.nytimes.com/2008/05/29/science/29brain.html` Monkeys Think, Moving Artificial Arm as Own, By BENEDICT CAREY, Published: May 29, 2008

[21] `http://www.reuters.com/article/2012/12/17/us-science-prosthetics-mindcontrol-idUSBRE8BG01H20121217` Mind-controlled robotic arm has skill and speed of human limb by Chris Wickham. 2012 Dec 17

[22] Antonio Damasio, The Feeling of What Happens, Body and Emotion in the Making of Consciousness, 1999, ISBN 0-15-100369-6, pg 292–294.

of brain. I have all kinds of emotions and desires constantly bubbling up. Sometimes these are telling me to do completely contradictory actions. Sometimes it feels like my heart is trying to tear me in two. And so emotion alone is not sufficient to tell me what to do. Reason alone on the other hand can only think things and guess consequences, it cannot decide between the different outcomes. And so I am left with reason and the newer portions of my brain cycling back to emotions in the evolutionarily older portions of my brain in a circle to try and figure out what I actually should do, what actions I should take, what words I should speak.

As for what I have learned about brains, I have had mixed emotions. Part of me has a touch of mad scientist fever, and thinks, cool, look at what we can do. Part of me is completely creeped out. I expect the future will be interesting, and things that would have been impossible decades ago will be possible, and we will need wisdom, and we will need to look at what reality is like and not what we want to be true. Humanity needs wisdom to navigate these changes.