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For longer than any adult should probably admit, I considered the possibility that I had discovered a portal to an alternate universe. As I turned over this momentous possibility in my mind. I was, very briefly, filled with a feeling of awe, of endless possibilities. I was overcome with a wild, intense, child-like wonder. I had goosebumps.

Stepping back and slightly to the side, while I dug around inside looked up and out my living room window. What I saw was sunshine streaming down, a green tree, some purple flowers, and the white siding of a house. Obviously, I had missed the bathroom entirely, broken through into the living room and was staring, through this hole, out my living room window and into my yard.

What can we learn from this anecdote? Well, once starters!

I share this anecdote because it both captures the feeling I get when I learn new, amazing Neuroscience, and it is a decent metaphor for scientific research. When doing science, you design a hypothesis, carefully plan your experiment, then take the plunge you drill that hole! When you finally peer at your results, often they are exactly what you predicted. Sometimes, the results are bewildering! Every once and a while, they are downright thrilling.

Perhaps the perspective-shifting experience of working on Neuroscience was why I was just a tad willing to consider the possibility that I had discovered an alternate universe. The feeling I had in that moment is the feeling I get when I learn something new about the brain

If fungal spores drift down and land on a foraging ant, that ant might become infected. At first, infected ants go about their business quite normally. After about a week, instead of continuing to forage for food, an infected ant will feel compelled to climb up a plant, to a leaf that is just about 25 cm above the ground. This leaf is always on the North/NorthWest side of the plant. She will climb to the underside of the leaf, and she will locate a leaf vein. The zombie ant will then bite down on that vein in what is referred to because she will grip this leaf vein continually, without moving, until she dies of the fungal infection growing inside her. re so well, the fungus thrives. It turns out that the temperature and humidity 25 cm above the ground on the N/NW side of plants is perfect for incubating the fungus. If scientists move a leaf with a zombie ant lower or

As a neuroscientist, what most fascinates me about this story, is how the fungus directs the zombie ant behavior in such a specific way. How does the fungus get the ant to leave the colony, climb up a plant to just a specific height? How does it know south from north? One imagines little fungal cells pulling on levers, consulting dials, and pushing buttons to drive the ant like a robot. But of

fungus highjack the nervous system of the ant?

As with many neuroscience stories, this one is still developing, and we do
things. The fungus converts most of the innards of the ant into sugars that it can digest. that
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irrationally fearful, often of water. They hallucinate and often lash out at strangers for no apparent reason.

Another example is Ergotism, which is the long-term effects of exposure to the fungus Ergot. This fungus can infect rye and other grains. When humans ingest Ergot, they present with hallucinations, delusions, and convulsions. This is probably the result of the inappropriate release of serotonin in the brain. Some have even provocatively proposed that this fungal infection was responsible for the madness that engulfed Salem Massachusetts in 1692.

A more subtle example of our brain chemistry being manipulated by a foreign organism comes from investigations of our microbiome. The microbiome is the collection of bacteria that grows on our skin and in our gut. These bacteria are mostly beneficial and actually critical for our continued good health. New evidence suggests that these bacteria in our intestines can alter our anxiety levels, and possibly even influence the gene expression in our brains, thereby altering our behavior in subtle ways.

The zombie ants teach us that the expression of proteins and balance of chemicals in our brains can have profound influences on our behaviors. And, that these characteristics may not be completely in our control, but may be influenced by external invaders.

Act 2: Mutants:

If that example seems a little disturbing, here is another story that --the genetic control of brain development. The instruction manual for building your brain is built into your genes and you will pass it along to your children. All of us have a blueprint for a beautiful, complex nervous system, and though it

can be shifted by external events, your developing self knew exactly what to do at every stage.

It is difficult to appreciate the enormity of the challenge of growing a nervous system from scratch, and how such a magnificent and complex structure results.

As Gerald Fishbach, a pre-eminent neuroscientist, has so nicely put it:

> The brain immediately confronts us with its great complexity. The human brain weighs only three to four pounds but contains about 100 billion neurons. Although that extraordinary number is of the same order of magnitude as the number of stars in the Milky Way, it cannot account for the complexity of the brain. The liver probably contains 100 million cells, but 1,000 livers do not add up to a rich inner life.

In the developing human brain, after each nerve cell is born, it must migrate into its proper position, and send out little tendri 792 r0912 0 61s29

So, today, I can announce the answer to the age- why did the neuron cross the midline? 5.850 peer-reviewed scientific articles confirm that To get to the other side! , folks!

Of course, the most interesting question is not why, but how.

the best way to approach this question? The answer is with mutants. Scientists purposefully but randomly create mutations in the genome of individual flies. They do this by hitting flies with X-rays or a chemical called EMS (ethyl methane sulfanate), which creates a variety of random mistakes in the genetic code. If these genetic mistakes are translated into proteins with mistakes, and the protein in question is important for development, we would see mistakes when we looked at the flies. In this case, if you are interested in the normal development of this ladder, you would screen lots of mutant flies for unusual looking ladders.

It should also be noted that labs often employ small armies of sharp-eyed undergraduates to sit at microscopes and sort through these thousands of flies! Once an unusual pattern is identified, neuroscientists work to identify the mutated gene and protein that gives rise to this pattern. From this, we can infer the normal function of that gene and protein in development.

This approach revealed that the midline was repelling our growing tendrils. We now know that the midline is made up of cells that release a protein called slit. A gradient is produced, with lots of slit right at the midline, and less and less as you move away. The tendrils growing on the side of the ladder can sense the slit it is almost like they can smell it they have receptors on the end of their growing tendril that sniff out this substance, and when they sense it, they avoid it, bypassing ladder rung after ladder rung.

this disorder, the growing tendrils in the brain because they and they get a bit lost as they grow. One of the main results of this is a disrupted visual system.

Slit itself has another known function in humans, which is to suppress the growth of tumors. When the slit protein is mutated or lost completely, people have an increased risk for some particular types of cancer.

There are a couple of broad lessons we can pull from this vignette, beyond the super-cool neuronal development piece. First, basic research is incredibly important. The story I told you about the developing fruit fly brain taught us something about an unusual human disorder and some types of cancer, though the people who

disorder. The knowledge accumulated about these proteins as a result of basic research over nearly two decades helped the relevant health research in humans go that much more quickly. It is nearly impossible to predict how and when basic research will be directly useful to humans, but it happens routinely.

For students asking fundamental questions about how various biological systems work, and there were beautiful examples of this on the posters this afternoon, the importance of basic research should be an inspiration. Others will build their work on yours, and who knows, you might even discover some important key that will be used years from now to unlock a human disorder.

The other lesson I like to pull from this story is about barriers. The slit barrier is a very real barrier, and very important. If you genetically alter it mutate it in a fruit fly you create a big mess an interesting and informative mess for the scientist but certainly a mess for this particular organism. So, this barrier is a positive and important and necessary thing---

cell that must cross needs to make the decision to simply ignore the barrier for a bit, pretend it is not there, even though the barrier itself

I like thinking about barriers in this way. They can be important, helpful, and useful, but there might be a time at just the right time and place, that barriers just need to be ignored and vaulted

Act 3: Grandmothers

Many neuroscientists think that the human brain is where it is AT!

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For example:

Nobel laureate Stanley Pruisner has said:

Neuroscience is by far the most exciting branch of science because the brain is the most fascinating object in the universe.

Others have referred to the human brain

This is all quite lofty, but I think my personal favorite comes from Richard M 90.025 300i

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since that time, people have found cells in the human brain that do recognize faces, but they respond to ALL faces, not just the face of one individual. The Grandmother Cell theory was used mainly as a strawman in theoretical arguments until just over 10 years ago, when neuroscientists found something incredible. Surgeons and scientists were
one particular she looked at pictures or did other activities. These scientists found what for all intents and purposes appeared to be a
grandmother, instead, it responded to
Jennifer Anniston.

Let me back up and explain
brain. The patient in this case had severe epilepsy. In some rare

seizures, the patient can opt to have surgery to remove the diseased portion of their brains. An important part of the planning for this surgery includes mapping the identifying the diseased area as well as regions critical for speech or motor control. To do this mapping, the surgeons can implant tiny electrodes, each less thick than a human hair, and listen in on neuronal chatter as patients go about their business. Many patients also volunteer to be involved in some experiments during this pre-operative phase, so they spend some time in front of a computer looking at pictures, watching movies, or listening to music while scientists record the activity of a bunch of cells in their brains.

In the process of showing one particular patient lotsW61 0 1 245Tf1.85 92 reW5/

presentation of a connection causes the brain to make a new association that essentially links two existing concept networks together.

So, while these experiments are on small numbers of cells in an even smaller numbers of people, it is changing how we think about the ways in which our brains encode information.

Families, parents, and relatives, even though your kids may be far away, rest assured you are represented in a neuronal circuit within that head. You are a constellation within the universe of their minds.

Thank you, families, for helping to shape the growing minds of the students here at Bowdoin. You have enriched their lives; be assured that their selves and indeed their brains are a physical manifestation of your love and care.

And students, you carry all the important people from your life in the circuits of your head. It is true that beloved family members might be represented on par with your favorite singer or movie star, but they are all in there, and you take them with you wherever you may travel.

Thank you, Bowdoin students, for being such a joy to teach, and a hearty congratulations on the honors received today. I thank you especially for the classroom light bulb moments that feed my soul.

I hope that these stories have given you a glimpse into the world of Neuroscience that I love so much. My wish for you is that you will find the academic subject
discovered an exhilarating new universe that here at Bowdoin, you will find that portal to a new, exciting intellectual world whether it be, music, literature, history, or science. May you get goosebumps as the features of this universe reveal themselves to