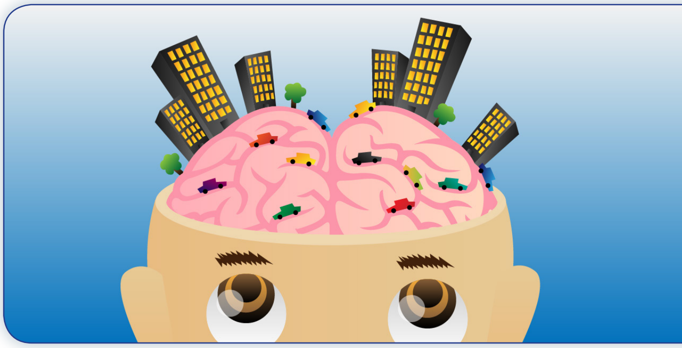
Neuroscience
Published: 24 April 2014
doi:10.3389/frym.2014.00017



Building the roads in the city of your brain

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Reviewed by:

Alanya
12 years old

Janelle
9 years old

"Are you ready to go into the spaceship? Remember to stay very still!" This is what you hear before the bed you are lying down on starts to slide into a long, tube shaped machine. You can almost imagine that it really is a spaceship, and that you, with your helmet, ear-phones, and small viewing screen, are the pilot, about to blast off into outer space! Your favorite space movie starts playing on the screen, and the machine suddenly turns on, making very loud sounds like "boop-boop-bleep," and you imagine you are in an alien spaceship battle. But this is no spaceship – it is a special machine called a *magnetic resonance imaging (MRI) scanner*, and it can take hundreds of pictures of your brain that help us to see how your brain works and what it is made of.

Your brain is the control center of your body; every movement, thought, and feeling that you have starts in your brain. But how does the brain do this? The work in the brain is done by *neurons*, a type of cell that looks like a tree with lots of branches going in all directions (look at the left side of Figure 1 to see what a neuron looks like). Thoughts and actions happen when different neurons "talk" to each other. In fact, there are neurons all over your body that get information about the world around you all the time. Neurons in your skin make you feel the things that you touch, neurons in your eyes are "turned on" by light to make you see, and neurons in the inside of your ears work when they hear noises around you. There are even neurons in your nose that react to chemicals in the air, so you can smell, and your taste buds work with neurons in your tongue that send the taste of your favorite food to your brain. All of these neurons in your body talk to other neurons, which all come back to your brain. Inside of your brain, all of the information collected is sorted out and forms your experience of the world. You can think of your brain as a city where houses and buildings are neurons, and messages traveling between them are like cars carrying people to go to work (look at the right side of Figure 1 to see a picture of this). In this paper, we will talk about the way in which the roads needed to send these important messages get better and faster as you grow up, allowing the city of your brain to get better and do more and harder things.

An example of neurons talking to each other is remembering something you learned in school for a test, such as "in 1492, Columbus sailed the ocean

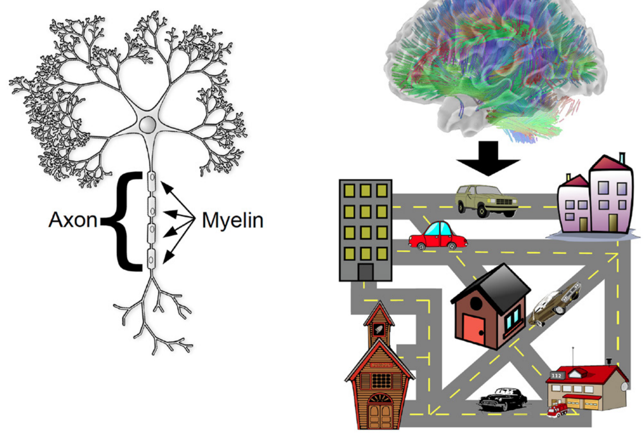

FIGURE 1 - The left side of the figure shows how a neuron looks like a tree, and where the axon and myelin are.
This right side is an illustration of how brain connections are like roads in a city. At the top, you can see a picture of the brain, with the connections shown as colored tubes. At the bottom, you can see buildings, roads, and cars. There are many connections, just like there are many roads in a city to get people where they need to go.

blue." First, neurons in your ears hear the sound of the teacher's voice and send it to neurons in your brain, so that the sound is turned into words and you can understand what the teacher is saying. Meanwhile, you may be looking at the board and writing down notes, and these messages from your eyes and hands are also sent to your brain. Once all of these signals have been sent to your brain, the information is shared with other neurons in your brain, so that you can remember it. Later, when taking the test on what you learned, these memory neurons send messages to other neurons in the brain, which send them to other neurons that tell your hand to move in such way to write the answer. A young kid may be able to gather all the pieces of information the teacher is giving, but it may be harder for them to remember these pieces of information later on and to use them on a test than for an older student. This might mean that neuron connections with the ears, eyes, and hands are already like for grown-ups, while the connections with memory neurons (inside the brain) get better as we get older.

So what happens to these connections among neurons as you get older? Well, when neurons communicate with each other, they do not use words; instead, they send electricity down a tube or "road" called an *axon* (look at Figure 1 to see where the axon part of the neuron lies). These axons can be very long, with the longest one running from the top of your back down to your big toe, and the information can get lost if it has to travel too far away. To solve this problem, your brain puts a covering, or *insulation*, around the tubes, to help the information get to where it has to go. Many things we see every day use insulation – can you think of any? Our neurons use a special kind of fat called *myelin* as insulation, to help the electrical messages move very fast to where they need to go. In our city, example shown on the right side of Figure 1, increasing myelin is like paving a street to ensure that cars can travel really fast, and that lots of cars can take that street. When you are young, axons are like dirt roads that you ca not drive too fast on. Adding myelin is like paving these roads so cars can drive faster and deliver the information to the different parts of your brain more quickly. In other words, your neurons can then communicate with each other faster and better than when the axons do not have so much insulation.

Scientists have known for a long time that the amount of insulating myelin increases in the brain as people get older [1]. However, scientists learned this by studying the brains of people who had died, meaning we did not know much about the brains of kids and teenagers when they were still alive. This changed when the magnetic resonance imaging (MRI) scanners we talked about were invented, as they enable us take pictures of your brain while you are still alive. A special type of MRI scan called diffusion tensor imaging (DTI) allows us to look at how well constructed the axons in your brain are [2], which includes myelin, and so we can see how they change as you grow up.

Now that it is possible to look at connections in the living brain using DTI, we did a study to see how the connections in your brain change as you get older. We decided to study kids older than 8 and teenagers, because even though they are very smart and can do many things adults do, they do a lot of silly things as well and can get into trouble [3]. Do you know any teenagers who do silly things? We also studied adults up to the age of 30, so we could compare their brains to the ones of kids and teenagers. Since boys and girls are different in many ways, we also looked to see if their brain connections were different as they grew up. We looked at many different connections in the brain and measured when they finished developing and looked like adult connections. Based on what you have learned already, do you think that all the myelin grew everywhere at the same time, or do you think it happened at different times?

If you guessed different times, you are right! You can look at Figure 2 for a chart showing all of the results we found. As you can see, some of the connections we looked at were already grown-up connections before 8 years of age. These included connections between your brain and other parts of your body that we talked about earlier and that are important for things like looking at a picture, feeling the cold in the snow and scratching your nose. Do you have a brother or sister who is younger than 8? Do these sounds like things they can do?

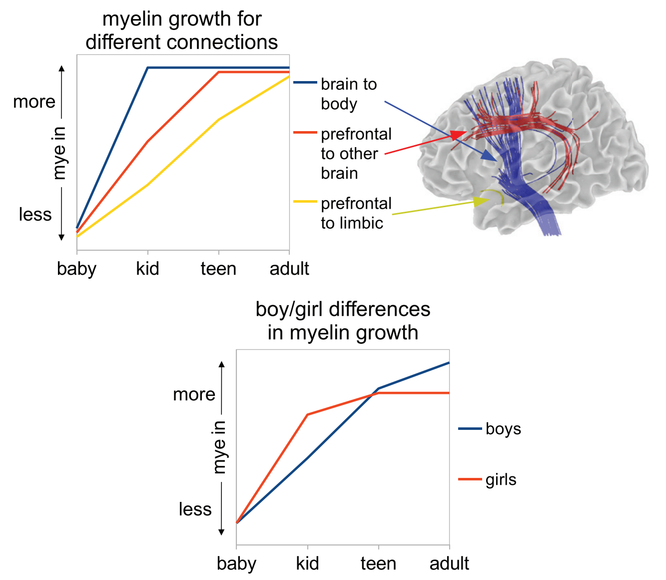

FIGURE 2 - This is the results from the study that we did. The top chart shows how connections from the brain to the body are grown-up-like in kids (in blue), connections from the prefrontal cortex to other parts of the brain slowly stop to improve in teens (in red), and connections from the prefrontal cortex to the limbic system (in yellow) continue to get better even in adults. On the right of this chart, there is a brain showing examples of these connections, in the same colors as the chart, and arrows point from the chart to the brain to help connect the two. The bottom chart shows how boys (in blue) take longer for their connections to get better than girls (in red), but end up growing stronger connections as adults.

Most of the connections in the brain continued to get better even in teenagers' brains. Many of these connections are to the *prefrontal cortex*, which is in charge of organizing the information going into your brain so it can decide what to do and make your body respond (look at Figure 3 to see where the prefrontal cortex is). Does this surprise you? If you gave the same, difficult math test to a 10-year-old and a 16-year-old, who do you think would do better? You would probably answer the 16-year-old, and that may be because the connections to the prefrontal cortex have more myelin in the 16-year-old's brain, helping that part of the brain talk to other parts of the brain that make it easier to pay attention and then make other parts act.

The most surprising and exciting finding in our study was that a few of the connections in the brain continued to grow, even in adults! These roads connect neurons of the prefrontal cortex, which helps us to think, to neurons in the *limbic system*, deep inside our brain (have a look at Figure 3 to see where the limbic system is), which helps us to have feelings. Have you ever ridden a roller coaster and felt excited or afraid, or eaten chocolate and felt that it tasted good? Did you ever get angry at your parents or at a friend when they did not do what you wanted them to? You are able to have all of these feelings because the limbic system gets excited. However, sometimes, we want to control the feelings, so as to stop ourselves from hitting somebody if they make us angry, for instance. This is when connections from the prefrontal cortex to the limbic system are important, so that the thinking can help stop the feeling from making you act when you are emotional and thus make sure you do not feel bad that you acted that way. Since the myelin in these connections

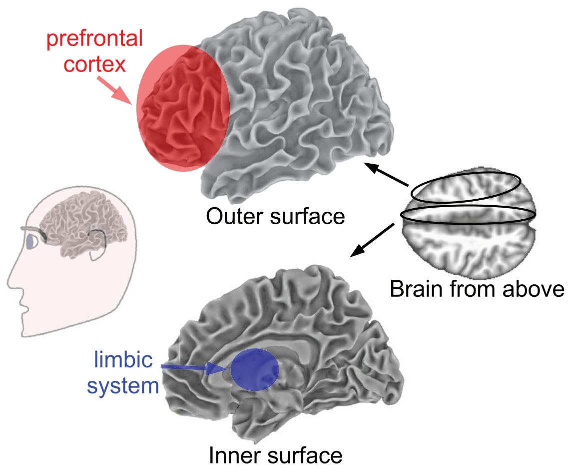

FIGURE 3 - This is an illustration of the brain, with the outer surface at the top and the inner surface at the bottom.
The colored circles show the parts of the brain we talked about in the paper, with the prefrontal cortex in red and the limbic system in blue. On the left, the face is shown with a brain inside, to give you a better idea of the way in which the brain fits within your head. On the right, we see the brain as if we were looking at the top of your head, and show where the inner and outer surfaces are.

keeps growing when you are in college and even after, this may help to explain why even adults are not always good at controlling their emotions.

Finally, as we mentioned earlier, we also looked at how connections in the brain are different in boys and girls as they grow up. We found that, for many connections, especially those to the prefrontal cortex, the girls' roads looked grown-up a few years earlier than for boys. If you are a teenage girl and you are reading this, you may not be surprised! One reason for this difference may be that girls usually start going through puberty (when your body changes and starts to feel grown-up) a few years before boys. In other words, changes in these connections may be related to puberty. But by the time they were adults, boys' roads had continued to grow to be bigger than the girls'. So everyone wins!

At this point you may be saying to yourself, "This is cool, but why is it important?" Well, one of the main reasons for studying how the brain works at different ages is to improve teaching in schools by basing lessons on kids' abilities. Hopefully, this will also help us make it more fun! Also, we know that some people have problems like autism or depression that can appear while they are kids or teenagers. Do you know anybody suffering from these problems? Unfortunately, we do not know how and why these disorders happen yet, but we think it may have to do with connections not developing the right way. By studying the brains of people without these problems, we can learn about the brains of people who may need help, and understand how to help them. The most important moral of the story is that, as you are grow up, your brain changes, so that the roads we need the most get better, helping us to become good at what we really need (like the language you speak), and the ones that we do not need so much slow down. You now know that, when you are young, the connections that help you control how you act are not very fast, so you may get mad and say something you later wish you had not. When we grow up, the roads that help us connect how we act to thinking about things ahead of time get stronger, helping us behave better to become great adults.

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Submitted: 24 February 2014; Accepted: 24 March 2014; Published online: 24 April 2014.
Citation: Simmonds, D., Goldberg, M., and Luna, B. (2014). Building the roads in the city of your brain. Front. Young Minds. 2:17. doi: 10.3389/frym.2014.00017

REVIEWED BY:

Alanya, 12 years old

I like to read, go shopping for clothes, and play video games. I like to eat ice cream, pizza, chicken wings, and spicy food! I like being an editor because I get to learn new things about science.

Janelle, 9 years old

I like playing legos, designing, and arranging things like my bedroom. I love eating crab but I am allergic! I am really into science, one day I would like to study medicine. Being an editor for Neuroscience articles is really fun and interesting.

AUTHORS

Daniel Simmonds

I am a brain scientist and medical student in Pittsburgh, PA, USA. I study how kids' brains grow and change as they get older, and hope to be a pediatric neurologist who treats kids with brain disorders. I also have many hobbies, including playing guitar and ukulele, building electronic instruments (soldering is fun!), doing yoga, and spending time with my wife Margot, our dog Sally, and our cat Jeanne-Claude.

Margot Goldberg

Margot Goldberg is a lifelong learner and science enthusiast who has worked on various problems in biology. She has wrangled strawberries and examined their chromosomes, worked on developing an HIV vaccine in West Africa, and explored a protein "chaperone" that helps other proteins do their jobs in the cell. Currently, she is studying to become a high school biology teacher and hopes to spread her love of science to her students! When she is not in the classroom, she enjoys knitting, singing, and playing guitar and piano, being in nature, and spending time with her husband, Dani, and their pets.

Beatriz Luna

She is the director of the Laboratory for Neurocognitive Development at the University of Pittsburgh. She studies that way peoples' brains change from childhood to adulthood. She is currently working on a number of studies that look at different aspects of these changes, including how we remember things, and whether or not rewards change how well we can play a game.