# I-LABS Module 2 Transcript

An amazing transformation takes place during the first 2,000 days of life. From the moment little Tomás belts out his first cry, to the moment he greets his kindergarten teachers, so much will have changed. Tomás has learned to talk, to walk, and to imitate his family and friends. He has gone from an infant who needs round-the-clock care, to a curious little boy, learning all he can about the world and how it works.

Children learn at an incredible pace during their first 5 years of life. With so much to learn before they start school, this is a wonderful and important process. From having the fine motor skills to tie shoes, to understanding other's emotions, it takes many skills to be school ready.

Let's dive inside the mind of our youngest learners – and take a peak at the incredible universe behind Tomás' big, bright eyes.

All of this learning is accompanied by a huge spurt of brain growth. At birth, a baby's brain is about one-quarter the volume of an adult brain. The rest of a newborn's tiny body is not even close to one-quarter of their adult size. If it were, the average newborn in North America would weigh about 40 pounds! Children's brains continue to grow, and quickly. By 3 years of age, a child's brain is already more than 80 percent of adult size. By 5 years of age, it's grown to about 90 percent of adult size. If our bodies grew at this same pace, the average American would be over 5 feet tall by the age of 5. Children's large brain size is why their heads are so big for their bodies. Over time, the rest of the body slowly grows and catches up with the brain and head.

Inside the brain, and extending throughout the body is a network of cells called **neurons**. Neurons are the building blocks of the brain. Working together, they form a complex signaling network. You can think of your brain and all of its neurons like your body's communications team.

The brain is made up of billions of **neurons**. Neurons are communicators. They have special features that allow them to send messages with rapid speed and efficiency. Neural messages drive everything we do, from moving our arms, to our emotional responses. These messages are actually little bursts of weak electrical current. Through these signaling bursts, neurons in our bodies and brains communicate.

**Dendrites** form a dense network of extensions or fibers. These branching structures are input fibers, receiving information from other neurons. The weak electrical currents that carry this information travel through the dendrites to the cell body.

The **cell body** is a collecting pool for all the incoming signals. The cell body processes these inputs, crunching the numbers. If the collective messages are strong enough, the neuron sends a message of its own.

This message, sent in the form of an electrical current, travels down a neuron's **axon**, or output fiber. Once the signal reaches the end of the axon, it is transferred to another neuron.

Connections between neurons are **synapses.** You can think of these connections as tiny information portals. Minuscule chemical messengers fly through the space between neurons. Traversing the tiny space, these messengers carry bursts of information from one neuron to another.

Neurons never work alone. And they aren't just connected to one other neuron in a chain. Instead, each neuron is one unit in a complex network of connections. Scientists estimate a single neuron can make up to 8,000 connections with other neurons. And the activity of one neuron influences many others. The adult brain contains about 86 billion neurons. If each of those 86 billion neurons makes 8,000 connections, the complexity of the system quickly becomes hard to grasp. The neurons in the brain form the most complex network in the known universe.

And we each have one! These trillions of connections in our brains are what allow us to learn and adapt throughout our lives.

While in the womb, billions and billions of neurons are born inside the developing brain. When an infant is born, they already have most of the neurons they will need throughout their lives. Learning happens when connections between neurons are formed. Because infants have so much to learn, babies are born without all the connections already in place. Some connections are there, but many still need to form.

You can think of this process a bit like a growing forest. A young forest is filled with saplings, but the tiny trees haven't grown big, arching branches yet. As the forest grows, the branches fill out, forming a dense wood. In the brain, the same thing happens. There are billions of neurons in the infant brain, but those neurons haven't formed all their connections yet. As a child grows and learns, a dense ecosystem of connections forms in the brain.

And it is a good thing that we aren't born without all those connections already in place. Each of us needs to build our own brain, with the specific skills and abilities that we will use throughout our lives. We each need to learn to speak our own native language, to build unique skills from playing basketball to creating music.

Every time we learn something new, we strengthen, shape, or form new connections between neurons in our brain. Our brains can make changes to the connections between neurons throughout our lives. Some synapses are strengthened, while unused connections sometimes become smaller or are removed. This way, our brains constantly adapt - they are flexible in our ever-changing environment.

The more you use a certain set of connections in your brain, the stronger it gets. For example, the more you practice speaking a second language, the easier it gets. In your brain, new networks of connections are constantly forming and growing stronger.

When young children are learning, they have to both build and strengthen many connections in their brains. Take learning to walk. Children are born with the connections they need to flex and extend their leg muscles. But they don't yet know the pattern of movements that will allow them to place one foot in front of the other. Step by step the connections between a child's brain and their leg muscles grow stronger. As they learn the pattern of placing one foot in front of another, they form new connections. These connections allow them to walk in a fluid, continuous motion. The more and more experience they have, the stronger the connections in their brains. The stronger the connections in their brains, the less they have to concentrate on the motion. Walking becomes a practiced task that takes little conscious thought.

Our brains go through the same process for any task that we need to learn. Once we have learned to read, we don’t typically think about the individual shapes of the letters. With enough practice, we formed connections in our brains that allowed us to recognize words as units. But we DID have to do this when we were learning. Think about when you come across a word you don’t know. Where do you start? You have to string the letters together, piece by piece.

Because children have so much to learn in the first few years of life, connections form rapidly between neurons. Brains of young children actually overproduce connections. The number of synapses in a human’s brain reaches its peak at about 5 years of age. But as our brains develop and become more mature, connections between neurons don’t form as quickly.

In fact, after a period of rapid development during the first 5 years, synapses begin to be removed. This process is called **pruning**. By the time we are adults, our brains have about half as many connections as they did when we were 5. Pruning connections in our brains is an essential part of brain development. By getting rid of connections we don’t need, our brains function more efficiently. Synaptic pruning allows us to become experts in living our own unique lives.

You can think of the pruning process a bit like taking care of a rose bush. During development, there is a period of great growth. The connections in the brain are “blooming,” similar to roses in the summer. Following that burst of growth there is a period of pruning. Excess brain connections that we don’t need are cut back, just like spindly rose branches. These extra connections actually hinder brain function. The result of this period of blooming and pruning is a brain – or a rosebush – that is healthy and thriving. Throughout development, there are multiple periods of blooming and pruning. These bursts occur at different times and in different regions across the brain. Scientists think that these bursts of blooming and pruning align with sensitive periods in the brain. **Sensitive periods** are times when our brain is particularly sensitive to experiences, and open to learning.

Over the course of childhood, we build our brains. This massive construction project is the result of both our biology and our experiences. Powerful biological processes provide the foundation, the raw materials and the basic building plan. But our experiences shape who we are.

Our biology provides the neurons, the mechanisms to connect them, and defines the structure of the brain. Our brains look very similar to the naked eye. Yet, at the microscopic level, our experiences influence how our brains are wired. Our experiences guide which neural connections form, become more efficient, and which will be removed. The more frequent an experience – whether positive or negative – the stronger those connections grow. Sensory input and interactions with people contribute to the intricate pattern of neural connections.

Biological factors guide the rate and extent of how experiences are processed for each individual child. But our experiences can shape how the biological factors are expressed. This combination of biology and experience contributes to all aspects of a child's development.

We know that experiences influence brain development. But teasing apart the details of this intricate dance of experience and biology has been a challenge. Now, cutting-edge tools are providing scientists with a new window into the developing brain. Brain imaging techniques like magnetoencephalography reveal what parts of the brain are active. Magnetoencephalography, or MEG, is able to detect the location and intensity of brain activity. As a child interacts with the world around them, we get a glimpse into their brain.

This brain imaging tool is silent, non-invasive and harmless. MEG can't read minds - scientists aren't able to tell what we are thinking or feeling using this tool. Instead, MEG can tell us what parts of our brain are active as we do certain tasks, like reading or listening to foreign language sounds. MEG detects the weak magnetic field produced by the symphony of neurons talking to each other deep inside the brain. This type of information helps scientists understand how different parts of the brain work together.

Using MEG, we can start to understand how the developing regions of infant brains begin to coordinate and network together. Baby Emma is a young research participant in the MEG machine. She sits quietly, as she watches a person wave toys to keep her engaged. As she sits, she is listening to language sounds through tiny headphones. All the while, the MEG is giving a readout of what parts of little Emma's brain are active. With MEG we gain a rare glimpse into the dynamic brain of a growing, learning child.

Using MEG, we are able to ask questions like: How do infants' brain activity change, as they learn something new, like language? With the MEG, we have begun to figure out how different parts of the brain begin to work together.

In this example we will look at how two regions of the brain that are important for speaking begin to work together. Newborns, 6-month-olds and 12-month-olds listened to speech sounds while they sat in the MEG machine. The MEG measured activity in brain regions important for 'speech perception' or listening. Activity in the 'speech production', or speaking area was also measured.

These images show the left side of the brain. Regions of pink and yellow color indicate where the brain is active. First, look at the image on the left. You can see that regions of newborn brains were active while listening to speech sounds. Now look at the image just to the right. In contrast, the "speaking" area of the brain wasn't very active. At this young stage, these two regions of the newborn brain aren't yet coordinated as infants listen to speech sounds.

Only 6 months later, the listening and speaking regions of the infant brain are active at the same time. This is just around the time babies are learning to babble. But the babies aren't actually babbling while they are in the MEG. They are just listening silently to language sounds. It is as if the infant brain is practicing, trying to figure out how to produce all the sounds it hears every day. This pattern of brain activity suggests that the speaking and listening parts of the infant brain are beginning to work together. Over the past six months, connections between these two brain regions have grown. The connections have strengthened as the babies listened to language.

At 12 months, many babies are beginning to say their first words. By this age, simultaneous activity in both the speaking and listening areas of the brain is even stronger. This coordinated brain activity is the result of both biology and experience. As infants hear more and more language, the connections, and the degree of coordination between these two brain areas grow. Early experiences with language are especially critical for infants. The infant brain is beginning to connect and coordinate these regions long before they utter their first word.

Early experiences matter. They drive brain development, shaping how this complex network grows and interconnects. And these experiences occur in the context of relationships. It is the moments and interactions we share with others early on that set the foundation for the rest of our lives.

The caring adults in Tomás' life helped him through his amazing transformation. They guided him as he grew from a dependent baby to a school-ready 5-year-old. They talked and cooed, immersing him in the sounds of language. As he began to talk, they encouraged him, patiently having conversations of growing complexity. They laughed together, they comforted his cries, and they set boundaries. By doing so, they created a stable, quality environment for Tomás to explore and learn.

You can learn more about the ingredients that contribute to quality interactions in Module 3.