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Concepts about the Brain:
Commitment, Plasticity, Pruning, and Memory

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There are several critical concepts about brain processes that describe how we create the unique brain we each have. They are cell commitment, brain plasticity, and pruning. These processes are what we are working with as we interact with children and adolescents. To understand these processes more fully, it is also helpful to understand how memory works.

Cell Commitment

The first critical concept of brain development is that of cell commitment. The brain is the only organ in the body that begins working before it is finished developing. So, we are born with a LOT of neurons and pre-formed connections between them, but the brain "doesn't know" which ones to keep. It needs to find out "*who it is*" and "*where it is*" and "*what it needs to know*." Then it will "know" what connections it needs to keep. This allows each baby to adapt his or her brain to their unique culture and family.

Brain cell commitment during a "critical period"[1] was one of the first concepts that I learned about brain development, and it set me on fire in regard to Early Childhood Education. In the mid-1980s, I read about brain cell commitment in an article on the front page of the *Oregonian* newspaper. The headline said something like this: "Mouse whiskers hold key to learning." Here is what the article was about.

> A researcher had done a study looking at the impact of experience on the developing brain using the whiskers of a mouse. A mouse has 66

[1] A "critical period" is a window in development during which a particular part of the brain has to be stimulated properly in order to develop normally. The development of vision in a baby has a critical period that spans the first 7 months of life.

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whiskers, 33 on each side of the upper lip. He discovered that these whiskers are arranged in a semi-circular pattern on the lip, and each individual whisker is connected to a specialized group of neurons in the brain. These cell groupings are arranged in a similar, semi-circular pattern in the brain. What this researcher discovered was if you remove a whisker from a newborn mouse within the first five days of life, the cell grouping in the brain, to which it is connected, *disappears*. If the whisker is removed AFTER day 6, the corresponding cell grouping remains. It is committed, because it had the necessary stimulation at the right time, coming through the whisker, to "tell it" to stay.[2]

How do mouse whiskers apply to our understanding of how children learn?

The first 5 to 8 years of life (the early childhood years) are very important because the brain is still actively developing its essential structure at a very rapid pace during this time. The early childhood years are considered to be a "sensitive" period[3] for learning. The brain is ready to learn what it needs to know, and actively seeks it.

The implication from this study for understanding child development is that the experiences that children have will determine the basic structure of the brain that they will use for the rest of their lives. And, WE (as teacher-caregivers and parents) are significant sources of those experiences during all of their waking hours.

After reading that first article, I was a little nervous looking back over the time I had spent with young children over the years in light of this new understanding. What *had* they learned by being my MY room for a significant amount of time? What exactly was my influence on them?

By extension I realized that repetition of experiences leads to commitment. The more a neural pathway is stimulated, the stronger the commitment. Commitment results when more and stronger connections (synapses) are produced by the neurons that control that behavior.

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[2] "The Brain: Development" Public Broadcasting System, 1986.

[3] A sensitive period is a window in development where it is especially plastic and sensitive to the influence of the environment. Some writers refer to these times as critical periods.

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Think about what happens when a toddler learns to jump off a step. They will step up and jump off 40 times in a row! And, they will try to repeat this with every step they encounter in any situation. Repetition leads to learning, although isolated, rote practice leads to *limited* skill development.

For learning to be meaningful, children need a full range of experiences: physical, social, cultural, linguistic, emotional, and cognitive. They need to work on all of these, all together, all day, every day. This is why in our early childhood programs, a LONG free play or free choice period (45 minutes to an hour) is so vital for preschoolers. It is in free play, indoors and outdoors, when children develop all their abilities in a coordinated fashion, by practicing a wide range of skills and abilities, *over and over again.*

Repetition of play activities and themes, (such as, throw and catch a ball, make a mark with a crayon, build with blocks, or play house) leads to a commitment of connections between neurons that are used over and over in these activities. These brain maps can be used later for similar activities. Making marks with a crayon develops skills necessary to writing and drawing. Throwing and catching a ball leads to being able to track moving objects and respond appropriately, as in driving a car.

The Brain is Plastic

The second concept is that "the brain is plastic" - which is called neuroplasticity. What do scientists mean by "plastic"? Think about all the forms that plastic can take: bags for groceries, containers for leftovers, shrink wrap on packages of fresh foods, PVC pipe, toys, furniture, bird feeders, and automatic pencils, to name but a few! The "wonder" of plastic is that it can take many forms, depending on what we do to it. Well, the brain, too, is plastic. It develops in unique ways depending on the experiences it has, just like plastic materials.

So this second concept, that the brain is plastic, tells us that the experiences that we have determine the *structure* of the brain (connections between neurons), and can impact all later thoughts, feelings, growth, and behaviors throughout the whole life. So, in a sense, we are what we do. According to Norman Doidge, "every sustained activity" that the brain has

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mapped, "including physical activities, sensory activities, learning, thinking, and imagining, changes the brain as well as the mind."[4]

Plasticity in the brain also means that when there is damage to an area of the brain (tissue damage or some other kind of damage that inhibits sensory input - like losing a finger), the brain can reorganize. The neurons that had controlled a lost finger, will soon be re-dedicated to moving the other fingers that are nearest to the one that is lost.

During the period of growth and development (birth to young adulthood) the brain is *especially* plastic because it is still creating its basic structure. The younger the child, the more plastic the brain is. So all these "sustained activities" have a big impact on children, and this includes all types of activities and ideas, says Doidge.

For example, children who learn to play a musical instrument fairly early in childhood (typically between 3 or 4 and 8 years of age), will have more connections between neurons (larger brain maps), in the places in the brain that are involved in playing that instrument. These can be maps for behaviors such as movement and sound perception. Studies that look inside the brain with high powered imaging machines show "that musicians who begin playing before the age of seven have larger brain areas connecting the two hemispheres."[5] This means that early music training can impact <u>other</u> areas of learning since the two hemispheres can "talk" to each other with greater ease and speed when there are more connections between them.

The impact on the brain of activities that we do is not limited to things like learning to play the piano. Doidge gives the following examples:

> "Brain scans of London taxi drivers show that the more years a cabbie spends navigating London streets, the larger the volume of his hippocampus, that part of the brain that stores spatial representations. Even leisure activities change our brain; [people who meditate and teach meditation] have a thicker insula, a part of the cortex activated by paying close attention."[6]

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[4] Doidge, Norman, M.D., <u>The Brain That Changes Itself: Stories of Personal Triumph from the Frontiers of Brain Science</u>, New York: Viking, 2007, 288.
[5] Doidge, op. sit., 290.
[6] Doidge, op. sit., 290.

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In spite of the impressive flexibility of the brain, plasticity has its limits. We can see this in people who have suffered a stroke. In spite of extensive physical therapy, they may <u>not</u> be able to recover all of their prior abilities. Additionally, neuroscientists have found that brain plasticity declines with age.

Pruning

The third critical concept about brain development is that of pruning. The experiences we have tell our brain which cells and which connections between cells to keep. The cells and connections that we do NOT use are weakened or actually lost, thus we call this process pruning. Another way you can think about pruning is that it is like a sculptor chipping away at a slab of marble to reveal a statue of a person. In <u>most</u> circumstances, pruning <u>gives the brain power and focus</u>, as though it has become "sleeker"!

In other circumstances, though, pruning can mean that we have <u>missed an opportunity</u> to develop more complex processes, such as problem solving, creating hypotheses, anticipating outcomes, and planning ahead. If we do not start to develop abilities early in life and keep working on them, like learning self-control, then the areas of the brain that govern self-control will lose their connections through pruning. This is the "use it or lose it" principle in brain science.

Let's take a look at an example of pruning in the first year of life, with the development of auditory discrimination. Auditory discrimination is the ability to hear the differences between sounds in the language you are learning. It is essential for language learning.

> During first 11-12 months of life, the part of the baby's brain, that recognizes and learns to carefully hear (or discriminate) sounds in the environment, begins to focus on the sounds of the language that is being spoken to the baby. In other words, the baby's brain is "programmed" to pay attention to the language of her caregivers, and makes a brain map of these sounds.

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> Babies are born with the ability to learn to "hear" (discriminate) the sounds of any of the thousands of languages humans have created. But, after 11-12 months, they lose this "universal" ability to discriminate ANY sounds in favor of focusing on the ones they have heard. By 11-12 months, a baby is babbling in his native language.
>
> According to Patricia Kuhl, of the University of Washington in Seattle, "once the critical period of auditory cortex development closes, an infant reared in a single [linguistic] culture loses the capacity to hear many of those [other] sounds, and unused neurons are pruned away, until the brain map is dominated by the language of its culture. Now its brain filters out thousands of sounds."[7]

This is an example of pruning, because the connections in the baby's brain that could have discriminated the sounds of other languages are now lost. This helps the baby focus on the sounds in the language that they hear in the home. And, because they have a lot of language to learn, they need to be able to focus on the important sounds for their linguistic culture. But, pruning of unused connections also explains how at six months a Japanese baby "can hear the English *r-l* distinction as well as an American infant. [But] at one year she no longer can. Should that child later immigrate [leave Japan and come to the U.S.], she will have difficulty hearing and speaking" the new sounds without an accent.[8]

Parents, who want their baby to be bilingual, must expose their baby to both languages, but in separate contexts: by who speaks which language to the baby, or by which language is spoken in the home and which language is spoken outside of the home. When I was a teacher in a parent co-op preschool in New York City, there was a young boy who attended whose family was Chinese and wanted their son to be fluent in both Chinese and English. Their approach was highly successful. They spoke only Chinese when inside their apartment. They also maintained other aspects of their Chinese culture inside their home. When they walked out the door of their apartment, they switched to speaking English. Their son was fully fluent in both languages at the young age of 3 ½ years!

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[7] Doidge, op. cit., 298-9.
[8] Doidge, op. cit. 299.

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Cell commitment, plasticity of the brain, and pruning of unused connections all work together to mold and shape each person's brain through the experiences that they have. The phrase, "every moment counts" refers to these processes. All experiences that a child has will shape their brain. Parents and teacher-caregivers are also helping children make memories and these memories create the "base" upon which children will build their lives.

How Do These Processes "Actually" Happen? The Biology of Memory

Neurons are the communication cells of the brain. Billions of neurons connect to each other in vast networks. Each neuron (cell) has a cell body (which contains the cell nucleus), dendrites (receiving projections of the cell body – with "spines" to increase surface area) and axons (sending projections which end in terminal branches that release neurotransmitter from the end of the branches.

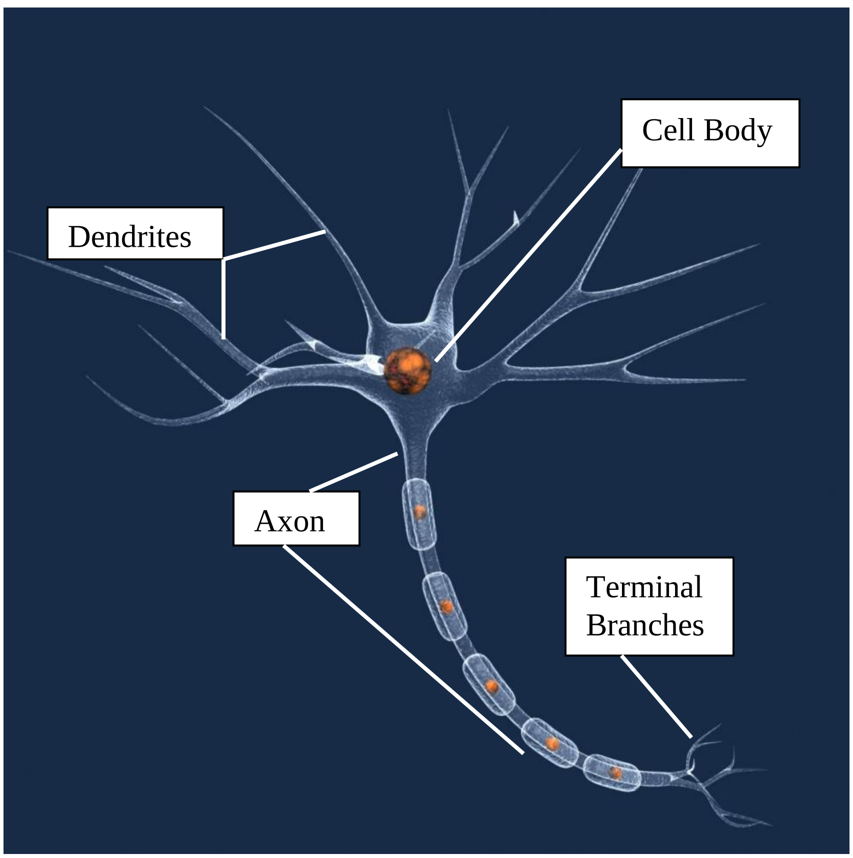

Figure 1: Parts of a Neuron Drawing by eraxion

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At each place where the terminal branch of one neuron makes a "connection" with another neuron is called the synapse or synaptic cleft. The sending neuron makes this connection by releasing neurotransmitter into the synaptic cleft and it "floats" across this minute space and stimulates receptors on the receiving neuron. This begins a "chain reaction" of stimulation along the many connections.

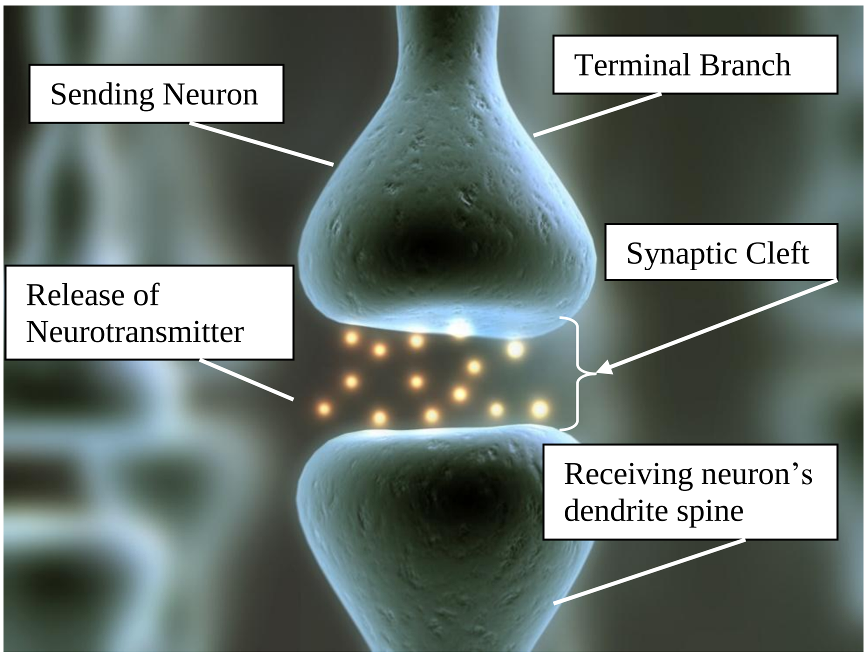

Figure 2: The Synapse Drawing by eraxion

When a connection between neurons is strengthened through repetition, the cells increase how much neurotransmitter they release from their terminal branches. This is what is happening in what we call working memory. This is the memory you can keep in your head as long as you keep using it. The first diagram[9] below illustrates a connection that has not been used much. Some of the terminals don't have any neurotransmitter in them. This is a "weak" connection.

With repetition or use, the cells begin release more neurotransmitter and they also begin to fill up the empty or "silent" terminal, thus increasing the release of neurotransmitter even more. This is illustrated in the second drawing below.

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[9] Squire, Larry R. and Eric R. Kandel. Memory: From Mind to Molecules. 2[nd]. Ed. Greenwood Village, Colorado: Roberts & Company, 2009.

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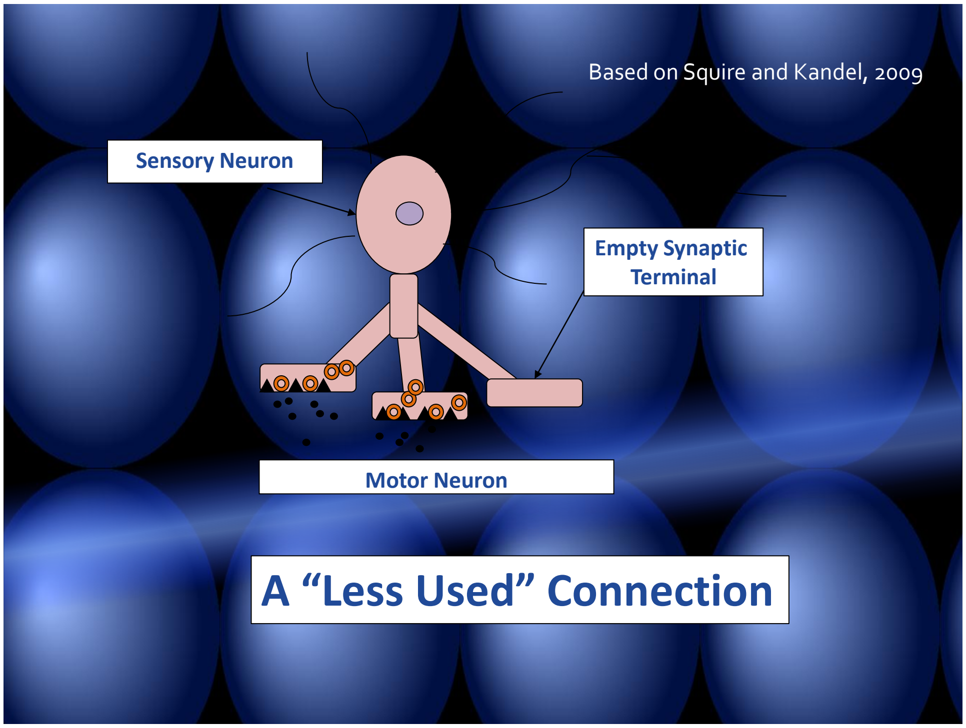

Figure 3: Biology of Memory – A "less used" connection

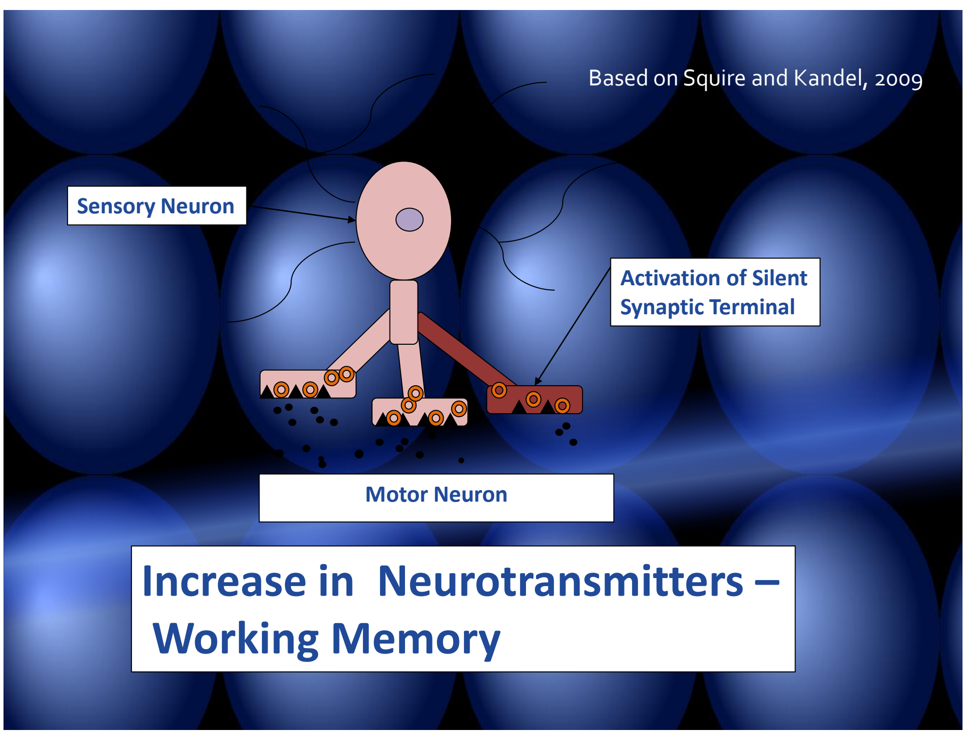

Figure 4: Biology of Memory – Working Memory

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When we REALLY use a connection, repeat something many times, it moves into what we call "long term" memory. What is happening in long term memory is that the terminal branches actually increase in number. The neuron makes the protein necessary to make new structure, and this becomes relatively permanent.

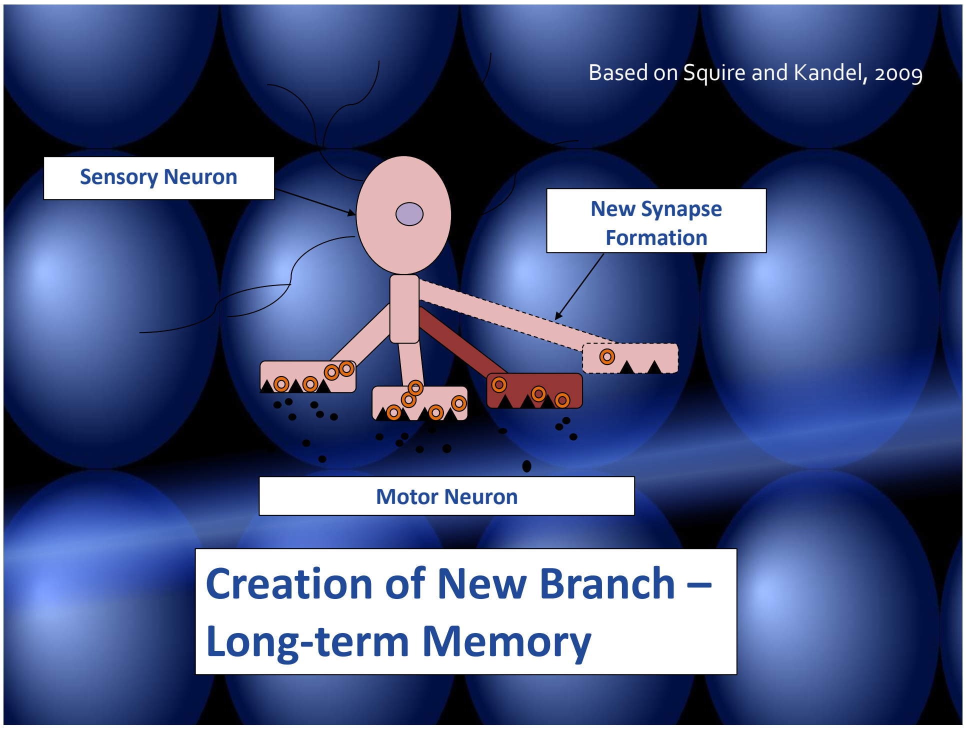

Figure 5: Biology of Memory – Long Term Memory

So, when we say that experiences change the very structure and function of the brain, and that these changes can be permanent, this is what we are talking about!

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