Looking Through the Lens of Science:
Tai Chi and The Dao of Brain-Building

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"Each day, each class, each practice session is a step toward a different future."
Daniel Coyle, The Little Book of Talent

Introduction

I live in New Jersey. An odd fact about this state has to do with Albert Einstein's brain. Opinions vary as to whether Albert Einstein's brain was lost or deliberately hidden in New Jersey, but it did reside undiscovered here for several decades after Einstein's death in 1955. A journalist named Steven Levy was given an assignment to find the missing brain and find it he did, in 1978, in the office that belonged to the pathologist who had conducted Einstein's autopsy. The discovery of the preserved brain created excitement among neurologists and samples of Einstein's brain were sent to Dr. Marian Diamond, a neuroanatomist at University of California. Dr. Diamond hoped to find a cellular explanation for Einstein's brilliance. Dr. Diamond compared Einstein's brain samples to tissue samples from "normal brains" and found only one significant difference: the proportion of white matter to grey matter was much higher in Einstein's brain than in the control samples. At the time of Dr. Diamond's research, grey matter reigned supreme in our understanding of how the brain worked and white matter was viewed as relatively unimportant packaging material in the brain. So Dr. Diamond's findings were disappointing to the medical community and the hope of discovering an anatomical explanation for Einstein's genius faded away. [1,2]

Grey Matter

It's peculiar that the anatomists who bestowed beautifully descriptive Latin and Greek names upon our body parts gave the name "grey matter" to our brain. Grey matter seems a shockingly general term for the command center of our body and isn't even accurate as the color of our living brains is pink.

The general nature of the name does accurately express centuries of frustration in trying to understand how the rather mushy stuff that fills our skulls works. We had no clue until the dawn of the 20th century when Santiago Ramon y Cajal applied the Golgi method of staining tissue samples to grey matter.

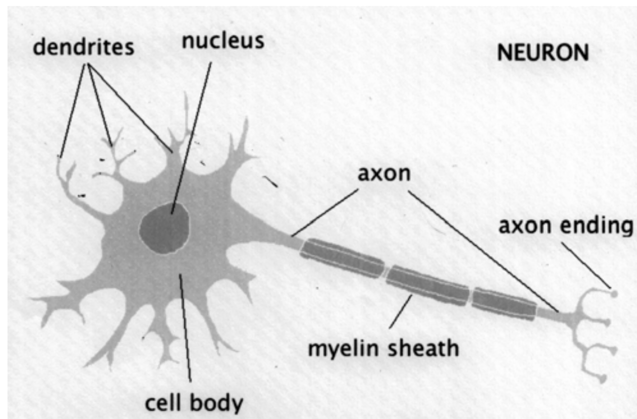

Figure 1

By staining very thin samples of brain tissue, Ramon was able to reveal discreet cells within the tissue that had a distinctive and identical structure. (Figure 1) He proposed a theory for the function of these cells, which came to be known as "neuron doctrine". [3]

Ramon's theory maintained that each neuron was an independent unit through which a signal passed in one direction only, like a car driven on a one-way street. When the car reached the end of one neuron street, it was able to jump across the small space that separated one neuron from another and travel along the next neuron. The tiny space between one neuron and the next became known as a "synapse". By passing or not passing signals across synapses, grey matter can direct information in a continuous complex flow in our brains rather like a telephone switchboard. [4]

We now know that the signal between neurons is an electrical impulse and that molecular activity in the synapses will pass or block the impulse to the next neuron. This means that our every thought and action is dependent on impulses sent along specific chains of neurons. Any thought or movement can be described as a specific chain of neurons. These neuron chains can be imagined as circuits with tremendous specificity built into them that will

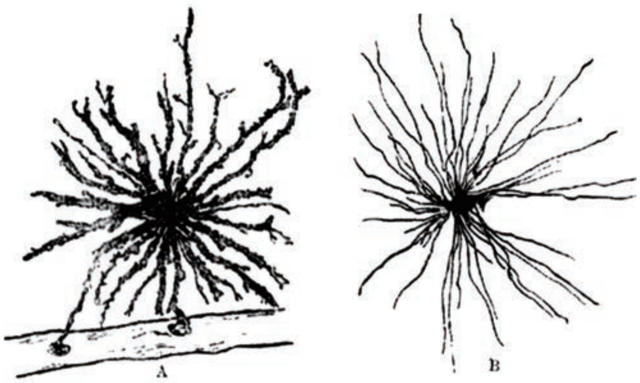

Figure 2

dictate timing and force of movements, coherence of thought, or fluency of spoken language. The more a circuit is used, the more developed it becomes and the less we are aware of using it. It becomes "automatic". Once a movement skill is learned or a language mastered, it flows naturally from us, as if we had been born with it, even though we know we were not. Skills we take for granted, such as walking, were gained through extensive practice when we were infants. [5]

White Matter

In addition to neurons, Ramon y Cajal saw something else in his stained samples of brain tissue. He filled notebooks with drawings of strange cells he called "spider cells". They looked like bullet holes shot through glass with fracture-like extensions radiating outward like a halo or like branching sea coral, or perhaps plump sausages strung on a string, or maybe a squid. (Figure 2) Even though these odd cells were as prevalent as neurons in the brain tissue, Ramon could not theorize a function for them. Like Einstein's brain, they were forgotten for decades. [6]

At the dawn of the 21st century, a new technology came along: diffusion tensor imaging. It allowed neuroscientists to measure and map brain development in living brains. Suddenly, the significance of Ramon's strange "spider cells" literally came into focus. [7]

What researchers saw with advanced imaging techniques seemed like something from a science fiction movie. They could see "myelination" in action: when a nerve cell fires, squid-like looking cells (known as "oligodendrocytes", or "oligos") grab the firing neuron and wrap around it. Each tentacle of the "oligo" cells curl around the neuron and squeeze a shiny white coating over the nerve cell. This white coating is known as myelin, an insulator for the nerve, helping the electrical impulse to flow through the neuron. In the process of myelination, the oligo cells wrap over and over nerve fibers as they fire, thus forming a complete neural circuit over time. [8]

Myelination is a slow process. Each filament of myelin can wrap around a single nerve fiber forty to fifty times. Myelination requires extended periods of repeatedly firing the same chain of neurons to complete a circuit with "automatic" capabilities. Aside from myelin production, it has been discovered that white matter cells, named glial

Glial cells, sometimes called neuroglia or simply glia (Greek γλία, γλοία "glue"; pronounced in English as either /ˈɡliːə/ or /ˈɡlaɪə/), are non-neuronal cells that maintain homeostasis, form myelin, and provide support and protection for neurons in the brain. They similarly interact with neurons in other parts of the nervous system such as in the autonomic nervous system.

As the Greek name implies, glia are commonly known as the glue of the nervous system; however, this is not fully accurate. Neuroscience currently identifies four main functions of glial cells:
To surround neurons and hold them in place,
To supply nutrients and oxygen to neurons,
To insulate one neuron from another,
To destroy pathogens and remove dead neurons.

For over a century, it was believed that they did not play any role in neurotransmission. That idea is now discredited. They do modulate neurotransmission, although the mechanisms are not yet well understood

Figure 3

cells, perform other critical jobs in our brains. (Figure 3) For the purposes of this article, we will focus on the importance of myelin formation.

Why Myelin Matters

People use the term "muscle memory" to describe the ability to perform skillful actions seemingly without thought. Muscle memory could be more accurately termed "myelinated neural circuits" that allow us to move in precise and effortlessly remembered ways.

If you ever wondered why a baby horse can stand and walk within minutes of its birth, the answer is myelin. A baby horse is born with key survival circuits already myelinated, unlike human babies who will have to practice for months to myelinate the neural circuits necessary to stand or walk. [9]

It is now known that myelin deficiencies are the underlying factor in many disorders of the nervous system such as dyslexia, autism, attention deficit disorder, post-traumatic stress disorder, and multiple sclerosis. [10]

If we look at the way multiple sclerosis first reveals itself, it seems rather obvious that neural circuits are "shorting out": your coffee cup slips out of your hand for no reason; a blank spot appears in your vision; your balance is not reliable. Multiple sclerosis (MS) attacks the nervous system in a very specific way. It targets oligodendrocytes, the glial cells that create myelin. This leads to the destruction of myelin throughout the nervous system and eventually causes the death of neurons. The progression of MS suggests that the myelinating glial cells do more to maintain the health of neurons than just creating insulation, but not all of their functions are understood at this time. The dependence of neurons on glial cells providing protective insulation raises the question of whether glia might need to experience impulse activity in neurons to function properly. It has been observed that stimulating impulse activity in neurons, which stimulates myelination, appears to be one of the ways to benefit patients with demyelinating diseases such as MS. [11]

The Relationship Between Myelination, Learning and Skill Building

While some researchers have focused on myelin's link to diseases of the nervous system, others have become interested in the role myelin may play in normal and high functioning people. As more and more brain imaging studies have been conducted, it has become clear that the more myelin is present, the more neural traffic can be directed through the brain. Myelination increases the overall information-processing capability in the brain. Increases in myelin, accompany learning and skill-building activities carried out over time.

The process of myelination follows a few fundamental principles:

1.Circuits must be fired. Myelin does not respond to wishing and dreaming and hoping; it responds to actions: electrical impulses traveling along neurons. It needs repetition of actions to happen and it is facilitated by "deep practice" which requires on-going attentiveness and sustained focus.

2.Myelin is universal. Our myelin doesn't "know" if it is being used to learn Chinese or how to play tennis: regardless of its use, it grows according to the same rules. Only circuits that are fired get insulated.

3.Myelin wraps, it doesn't unwrap. Once a circuit is insulated by myelin, consider it permanently installed unless compromised by disease or disuse. Based on this principle, the old adage "practice makes perfect" should be revised. "Practice makes permanent" is more accurate. What and how we practice shapes the outcome of the circuits.

4. Age matters. In children, myelination occurs in a series of waves of peak cellular activity, somewhat dependent on genetics but also on activity and levels of external stimulation. These peaks last into our 30's, creating a series of optimal learning windows. After age 50, we experience decline in our ability to myelinate but we will always have some active oligo cells producing myelin on demand. The decrease in active oligo cells explains why it is difficult to learn new skills in our senior years, but it also points to the reason why it is so very important to do so and to continue to practice skills that we have already developed in order to maintain as much white matter in our brains as possible. [12]

Tai Chi Practice and Brain Development

A brain imaging study conducted in China in 2012 compared brain thickness between two groups of participants. One group was comprised of experienced Tai Chi Chuan practitioners, with median age of 52 and median level of Tai Chi practice 14 years. The other group was matched according to sex, age, and physical stature but were not Tai Chi practitioners. The study found a statistically significant difference in cortical thickness between the Tai Chi group and the control group. The Tai Chi group showed more brain development in the areas of the brain responsible for observation, execution of motor tasks, mediation of visual-motor tasks, sensory perception of body parts, and integration of emotion and cognition. [13]

These findings support the discoveries of neuroscientists that practice may not make perfect but it does make myelin. Those who have studied skill-building activities and practice techniques have identified some principles of practice that facilitate myelination. Interestingly, these practice principles draw a perfect blueprint for a student's journey into the study of traditional Tai Chi Chuan.

1. Skills are learned by repeating small pieces of the overall skill over and over with critical attention paid to correcting errors and perfecting performance until the pieces can be performed with repeatable precision. In Tai Chi parlance, we say this is making your Tai Chi form "standard" and it is understood that this process will take years. The Tai Chi teacher provides students with explanations and demonstrations of every move in the form and divides every move into smaller pieces so that every detail is apparent. The student imitates the teacher and the teacher gives corrections. The student repeats and repeats the learning process until precision is attained in doing every posture.

2. When the standard of precision is reached, the student has developed myelinated neural circuits, "muscle memory" for each movement and posture. In the lexicon of skill development, this type of skill is termed a "hard skill". Hard skills are learned by being precise and consistent in every practice session. The ABC's of hard skill development are Always Be Consistent. Hard skills are like a high quality watch; they are accurate and predictable.

3. Soft skills are next in the learning hierarchy. Soft skills add agility, flexibility, and adaptability into the skill mix that results in the ability to make the best choice of action given varying conditions and circumstances. In the Tai Chi world, a little soft skill is added to our solo form when we perform in a group. Here we have to make minute adjustments to the people around us so that our timing and spatial relationships are uniform throughout the group. However, it is push hands practice that really develops our soft skills. Any student who goes from practicing the solo form to practicing push hands knows how steep the learning curve is to attain the adaptability and agility of soft skill. Soft skills require the three R's: Reading, Recognizing, and Reacting. Attaining soft skill means you can quickly recognize a pattern or a possibility and choose the best action relative to that moment in time. Soft skills require practicing in "real time" with constantly variable conditions.

4. Hard skills and soft skills are developed through different methods of practice and they use different structures within our brains and build different kind of circuits. The payoff for developing as much skill as possible, whether hard or soft, is white matter. Our brain literally grows when we develop skill, via the myelination process. [14]

Conclusion

Now that brain imaging techniques have been developed so that living brains can be studied, there is no longer any question that the human brain is built, not born. Einstein's brain is a testament to how active a brain can be, how many different circuits of learning and association, hard skills and soft skills, can be developed and myelinated over the course of a lifetime. For healthy aging, myelin matters. As a natural part of the aging process, myelin starts to split. This is why older people move more slowly than younger people; the speed of nerve impulses slows down as the myelin coating begins to show wear. The good news is: WE ALWAYS RETAIN THE ABILITY TO ADD MORE MYELIN BY FOLLOWING THE RULES OF SKILL DEVELOPMENT. Myelin is alive, it is always being generated and it is always degenerating. Even when myelin is breaking up, we can still build it, right to the end of our lives. The more myelin we have, the healthier our neural circuits are. We can maintain robust brain function throughout our life spans. We need myelin and myelin needs years of deep and skillful practice to grow. What better inspiration do we need to study and practice Tai Chi? [15]

Footnotes

1.Levy, Steven, *I Found Einstein's Brain.* www.StevenLevy.com
2.Fields, R. Douglas, *The Other Brain,* Simon & Schuster: 2010, pg 7
3.*Ibid.* pp. 8-19
4.*Ibid*. pg. 10
5.Coyle, Daniel, *The Talent Code,* Bantam Dell: 2009, pp. 36-37
6.Fields, *op. cit.*, pg 11
7.Coyle, *op. cit.*, pg 40
8.*Ibid*. pg. 41
9.*Ibid,* pg. 68
10.*Ibid*, pg. 40
11.Fields, *op. cit.*, pp. 166-170
12.Coyle, *op. cit.*, pp. 44-45
13.Wei G-X, Xu T, Fan F-M, Dong H-M, Jian, et al. (2013) *"Can Tai Chi Reshape the Brain? A Brain Morphometry Study."* PLoS ONE 8(4): e61038. doi: 10..1371/journal.pone.0061038
14.Coyle, Daniel, *The Little Book of Talent*, Bantam Books: 2012, pp. 17 – 28
15.Coyle, op. *cit., pg* 215