Why the Brain Works the Way it Does: Evolution and Cognition from Movement

The answer to why and how the brain works the way it does and why it may dysfunction, is based on its evolutionary development. There are two main characteristics that, above all, make human beings unique among all organisms: (1) humans are bipedal, and (2) we have a much larger brain in relation to body size, especially the cortex. The simple act of standing and walking upright is the most sophisticated and complex movement that any organism has yet achieved. Because of the intricacy of that movement, the brain developed to a greater size and complexity. The human brain has grown due to its dependency on the increased environmental stimuli that walking upright creates.

The one pre-adaptation that clearly occurred before the growth spurt of the brain was the ability to stand upright. Human beings are bipedal, which means we walk on two feet instead of four. We are the only organisms who can do this all the time. Monkeys can stand up at times, but when they want to go anywhere, they typically do it on all fours. The first ancestor who walked with two legs is thought to be Lucy, an Australopithecine discovered by Dan Johansen and who is thought to have died in what is now known as Ethiopia 3.5 million years ago. The impetus to stand erect and walk on two feet has been universally recognized as the one possible characteristic that made Lucy different from the creatures around her. At that time, no other major physical change occurred. Our vision was the same as it is now, as was our hearing, and the other bodily functions. The only thing that changed was that we stood straighter and our brain grew larger. From the point in time of this tripling effect over a mere few million years and when our ancestors achieved a fully upright position, the brain stopped growing in size but continued to grow in complexity and intricacy. The two are obviously tied together but how this understanding relates to our brain’s function now needs to be examined.

One theory is that standing upright increases heat to the head and therefore, the need to decrease heat production arose. The increased need to dissipate body heat resulted in increased blood supply to the head, which stimulated increased brain growth. Although increased blood may have played some role, when we understand how the brain cells grow, we know that just supplying them with increased blood and oxygen will not increase their size unless there is an increased stimulus demand first, which causes an increased use of oxygen and not the other way around. Brain cells that are supplied with plenty of
oxygen, but are not stimulated, will die. How did it change its configuration as it evolved its huge size? In general, large primate brains have relatively expanded volumes of neocortex. In a chimpanzee, for example, the neocortex forms a larger proportion of total brain volume than it does in the smaller brain of a monkey. The general trend for primates predicts that a brain as massive as ours should have an exceptionally large volume of neocortex, yet the human neocortex turns out to be more voluminous than expected. In addition, the regions devoted primarily to thinking are especially large. These regions, known as the association cortex, are the ones that are not dedicated to sensory or motor functions. It appears that the evolutionary expansion of the human brain automatically produced a disproportionately large volume of tissue devoted to thinking. Simply put, brain size greatly outstripped body size, and the excess brain tissue, or the parts not required to control the body, was available for higher functions.

Recent theories on how higher mental functions arose in this excess tissue have been proposed by Jerison (1985) which he calls the principle of proper mass. According to this principle, the amount of neural tissue devoted to a particular function is appropriate to the amount of information processing that the function entails. In effect, as it grows, the brain organizes itself according to this principle. In both monkeys and humans, the phase of fetal brain growth or neurogenesis begins about 40 days after conception. This phase lasts for about a 100 days in monkeys and about 25 days longer in humans. Neurogenesis occurs deep within the brain, and the neurons assume specific positions in the neocortex by migrating to locations that are specified by genes. Through their migration, the neurons build the six layers that make up the neocortex, starting with the innermost layer and ending with the outermost layer. The human neocortex is identifiable about 2 months after conception, and cell migration ends by the end of the fifth month.

Another aspect of maturation is myelination, a process in which fatty sheaths enclose neurons, insulating them and improving their ability to conduct electrical signals. To some degree, the connections that neurons make with one another are genetically programmed, but the genetic controls are imperfect and feedback from the body and its sensations influence both the production and the elimination of specific connections. Cells that form synaptic connections between neurons receive more nutrition and stimulation than those that do not, and those whose synapses fire off the most frequent messages are particularly well supplied. This is the process of synaptic stabilization, much of this natural selection at the cellular level takes place prenatally, but the process continues well into the postnatal period. A human baby enters the world with perhaps a trillion synapses connecting its cortical neurons, but a large fraction of these disappear during the first decade after birth. Predictably, the maturation of brain tissue parallels the maturation of brain functions. The development of brain and the body involves reciprocal feedback systems. Maturation of a particular sector of the brain stimulates activity in a corresponding area of the body or in a connected area of the brain. The stimulated function then matures more rapidly through use, but this use stimulates development of the area of the brain that controls it. As a human baby grows into a toddler and then a school age child, the brain permits interactions with the environment. This relationship also molds the developing brain, however, favoring the fixation of beneficial neural maps and allowing pruning of useless neural connections. The result is that although genes specify some traits of the developing brain, particular neuronal maps are created through interaction with the environment, especially in the later stages of development. The body automatically sends fibers to the brain proportional to the body’s size. This means that when the human brain, in growing so large, outstrips the body, there is no way the body can recruit the excess neurons and neuronal connections that develop within the brain especially when the brain suddenly evolves to a much larger size without a corresponding expansion of the body. The sensory and