# Inhibition and Purkinje Cells of the Cerebellum

*John Henes and Indira M. Raman*

**JH:** Inhibition is one of the most difficult concepts to teach. It is unfamiliar to most new students, it takes time and repetition to learn, it is difficult to explain in words, and for many students it is confusing. When I first started taking Alexander Technique lessons, my first teacher, Joe Armstrong, who was very good and precise in explaining the Alexander Technique, could not, at least to my satisfaction at the time, explain the concept of inhibition to me. Recently, I found out through one of my students, Indira Raman, who is a neurobiologist and professor at Northwestern University, that there are indeed brain cells that do stop motor activity and are responsible in large part for learning new motor skills. These cells are called Purkinje cells.

**IMR:** I have been studying the properties of Purkinje cells for more than twenty years. I have also played piano as an amateur since childhood. One thing I learned long ago is that scientists and musicians tend to use the same words in different ways. Terms that are literal or concrete for one group can be applied figuratively or metaphorically by the other, and musician-scientists alternate definitions depending on the domain in which we are operating. So when I first started taking Alexander Technique lessons with John Henes a few years ago, and he spoke of "letting go," I did not ask the obvious scientist's question, which would have been "let go of what?" Instead, I waited to learn the meaning of the phrase in the new context. And when he mentioned "inhibition," although I was mildly entertained to hear him invoke the term that describes the primary subject of my scientific research, I took it for granted that he was not using the word in the neurophysiological sense, and I did not try to form a connection between his area of expertise and mine.

In the world of neuroscience, "inhibition" is complementary to "excitation"—these words describe the two main ways in which brain cells, called "neurons," send signals to one another. What neurons do can be summarized fairly simply. The role of the brain is first to notice or detect aspects of the physical world—things both outside and inside the body—then to evaluate or integrate them, and finally to take action, either by moving or not moving. This cycle of detecting, integrating, and taking action can happen slowly, over minutes, days, or even years, or it can happen rapidly, in a tiny fraction of a second. The detection is done by specialized cells in our sense organs (eyes, ears, nose, tongue, skin, etc.), the integration is done by neurons (of which there are billions), and the action is done by muscle cells. The sensory cells report the presence or absence of light, sound, odours, flavours, touch, etc. by releasing chemicals, called neurotransmitters, which signal to neurons; those neurons, in turn, release neurotransmitters that signal to other neurons and eventually to the muscles. It is these chemical signals that make the muscles contract or relax so that they carry out simple reflexes like a knee-jerk, complicated motor sequences like the playing of a concerto, or considered responses like a spoken answer to a question. The chemicals come in several varieties. Some neurons release neurotransmitters that make it more likely that the next cell in the chain will send a signal—a process called "excitation." Other neurons release neurotransmitters that suppress the signals of the next neuron. In neuroscience, this process of one neuron making other cells keep silent is what is technically called "inhibition." When John spoke of inhibition, however, I interpreted the word generically—I figured he was just taking a break from telling me to "let go" by telling me to inhibit "holding on."

**JH:** I have been teaching the Alexander Technique for nearly 40 years, and for most of those years I have been telling my students that there is a brain cell someplace up here, pointing to my head, that says "let go." This was just an amusing way to get across to my students that they had to search for a way of thinking that allowed them to establish inhibition for themselves. We aren't educated to make use of this way of thinking, and we have to get more familiar with letting go and thinking about process and somehow exercising this brain cell.

**IMR:** It was many lessons before John invoked the brain cell imagery with me. He had been talking about habits, which I was slowly coming to understand were some of the things I was supposed to let go of. "Somewhere up there is a brain cell that will help you let go and you have to find it," he said. I have actually spent a good chunk of my life actively finding brain cells and figuring out what they do, but rarely in my own head. The cells that I study, in rodents, chicks, and fish, are in the cerebellum. In humans, the cerebellum is in the back of the brain, tucked underneath the more familiar part that is usually illustrated as resembling a wrinkled boxing glove viewed from the side. The cerebellum, which is more wrinkled still, is often left out of popular drawings.

The cerebellum helps control movement—when people or animals have cerebellar neurons that don't signal properly, they become uncoordinated and imbalanced. And whenever a person is learning a new motor skill, it's the neurons in the cerebellum that receive signals about what is being sensed, and what movements are being made, and whether those motions are giving the desired result—say, whether an arpeggio is played accurately—which usually doesn't happen when the person is just beginning to learn something new. Those neurons in the cerebellum are also the ones that measure the difference between what *is* happening and what *ought to* happen, and they change their signals—how much and how fast they release neurotransmitter—until the movement is modified enough to be made correctly and automatically. In other words, what is colloquially referred to as "muscle memory" is actually the job of the cerebellum.

Of course, I knew that what John was trying to teach me would require motor learning and so the cerebellum was probably involved, but I also knew that several parts of the brain work together to regulate movement; in fact, neuroscientists spend a good deal of time debating which part does what, by how much, and when. I wasn't yet even really clear about what I was trying to master, so there was no point in arguing for the primacy of the cerebellum, even to myself. Besides, the abstract knowledge of what *should* be going on within the brain didn't seem particularly useful when I couldn't actually get my brain to do it. Nevertheless, when John pointed at his temple and mentioned that there was a brain cell that I should be looking for, I pointed at the back of my head. "Well, it's probably back here," I replied.

The cerebellum contains several different kinds of neurons, but the main cells that cover the wrinkly surface are the Purkinje cells. They signal to neurons in the core of the cerebellum, called the cerebellar nuclei. The neurons in the cerebellar nuclei, which "listen" to Purkinje cells, have a fairly direct control over movement, with just a few intervening neurons to convey their messages: when neurons in the cerebellar nuclei send out signals, muscles usually contract.

When looked at one at a time, Purkinje cells are visually beautiful neurons (*Figure 1*). Each has a "cell body"—the rounded central part that houses the nucleus—which is quite large compared to other neurons. At one end, the cell body stretches out into a "dendrite" (occasionally two) that is broad, flat, and gorgeously branched, so that it looks like a leafless fruit tree trained against a wall. The dendrite, which functions as a sort of antenna, contains hundreds of thousands of detectors for chemicals from other cells, through which a Purkinje cell collects the information about what is currently being sensed and what movements are about to be made. The dendrite translates the chemical signals into electrical signals. At the other end of the cell body, the Purkinje cell narrows into a long wire-like structure called an "axon," which sends the electrical signals to the cerebellar nuclei. A tiny dollop of neurotransmitter is released for every electrical signal that reaches the end of a Purkinje cell. The neurotransmitter suppresses the signals of the cerebellar nuclei. The role of Purkinje cells, therefore, is inhibition.

**JH:** I often refer to this quote from Frank Pierce Jones when talking about inhibition. "It is said that a simple way to trap a monkey is to present him with a nut in a bottle. The monkey puts his paw through the bottle's narrow mouth, grasps the nut, then cannot withdraw his paw because he will not (and hence cannot) let go of the nut. Most people are caught in monkey traps of unconscious habit. They cannot escape because they do not perceive what they are doing while they are doing it."[1] I think it is a fun quote that also gives one pause to think of all the monkey traps waiting to catch us in our daily lives.

**IMR:** Inhibition by Purkinje cells does more than just prevent movement altogether by shutting off cerebellar signals. The patterns of inhibition can be complex and sophisticated, instructing the cerebellar nuclei exactly how long to wait before telling a muscle to contract—down to a thousandth part of a second—and how to get precisely the right amount of movement and no more, without "holding on" to a particular set of contractions. Many Purkinje cells, working together, can delay one set of muscle movements so that they occur only after a different set of movements. In that way, they can produce sequences of motions that are the building blocks for complicated, coordinated motor behaviour, like walking, dancing, or playing an instrument. They can make initially difficult or awkward movements become automatic, turning them into habits. But they can also pay attention to new information—sensations like pressure and pain, and maybe even the neuronal signals that we call thoughts—and inhibit our previously learned habits, teaching us more adaptive actions instead.

**JH:** My first teacher tried many times to explain to me that inhibition was not just something physical but could also give us choices in the way we think. I had many lessons before I discovered the truth in those ideas. Many of my students have reported their observations of improvement in performance anxiety, control of temper, feeling more comfortable with themselves and other "psychological" changes besides the more evident physical changes such as posture, ease of movement, and improved breathing.

Another quote that I like has to do with the observations of John Dewey who wrote introductions to three of the four books that F.M. Alexander wrote. "The greatest benefit he got from lessons, Dewey said, was the ability to stop and think before acting. Physically, he noted an improvement first in his vision and then in breathing. Before he had lessons, his ribs had been very rigid. Now

[1] Frank Pierce Jones, *Body Awareness in Action* (New York: Schocken Books, 1976), 4.

they had a marked elasticity which doctors still commented on, though he was close to eighty-eight. Intellectually, Dewey said, he found it much easier, after he studied the technique, to hold a philosophical position calmly once he had taken it or to change it if new evidence came up warranting a change. He contrasted his own attitude with the rigidity of other academic thinkers who adopt a position early in their careers and then use their intellects to defend it indefinitely."[2]

**IMR:** One of the most interesting aspects of current cerebellar research is that we are coming to the realization that the cerebellum does more than just change the way our limbs and trunk move. It seems to participate as well in brain functions that are classed as "cognitive"—what most people think of as "thinking." Through the process of comparing what is intended with what actually occurs, the cerebellum appears to play a general role in predicting what will happen and adapting accordingly, by sending signals to muscles as well as other brain regions. In fact, the cerebellum is in constant conversation with many other parts of the brain, including the basal ganglia, which helps decide whether a physical action will be taken, and the cortex, which is usually credited with conscious action. Remarkably, the cerebellum is the brain region that is most frequently seen to be physically disrupted in autism spectrum disorder. Since this condition is often characterized not only by habitual, stereotyped movements, but also by rigidity of behaviour, it seems likely that a healthy cerebellum may help provide flexible responses, both physical and mental.

The full effects of Alexander Technique, which I have barely begun to grasp, undoubtedly involve an extensive dialogue among many brain regions and the body. But the more that John teaches me—often wordlessly, through his gentle adjustments of my actions—the more I become convinced that, despite our different worlds of Alexander Technique and neuroscience, his "inhibition" is likely closely related to my own.

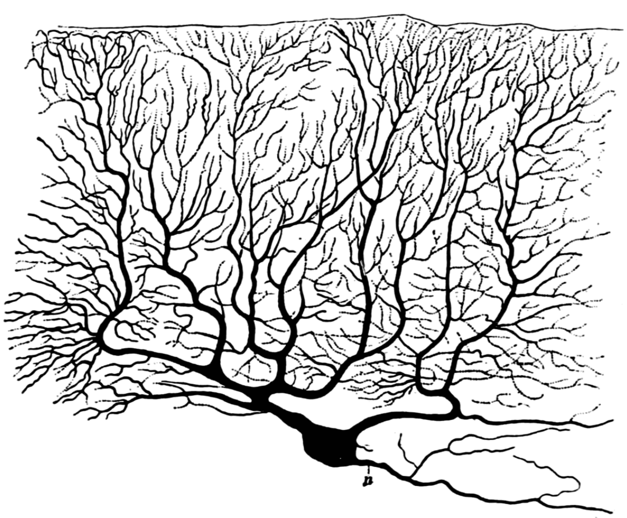

**Figure 1.** Image of a human Purkinje cell. From Kölliker, A. (1896) *Handbuch der Gewebelehre des Menschen.* Band 2. Leipzig, Engelmann; reproduced in Nieuwenhuys, R. (1967). Comparative anatomy of the cerebellum. *Progress in Brain Research.* 25:1-93.

[2] Frank Pierce Jones, *Body Awareness in Action* (New York: Schocken Books, 1976), 97.

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