Muscular activity, from a tiny twitch in the corner of my eye to the full mobilization of my body in walking or running, I cannot move without touching myself internally and externally; these internal and external pressures and frictions inform me about my own body and its activities in exactly the same way that my sense of touch informs me about external objects. I am not tactilely aware of things, not even my own body parts, unless I push or rub up against them in some way.

**The Kinesthetic Sense**

All of these tissue distortions and sensory responses taken together are what give me my kinesthetic sense, my feeling for my body's size and shape, the locations of all my joints and limbs, and what all of them are up to. "It is important to remember that in its simplest form, the nervous system is merely a mechanism by which a muscular movement can be initiated by some change in peripheral sensation..." All of these peripheral sensations initiate some kind of muscular response. What is equally important to remember is that every one of these muscular movements in turn initiates a reciprocal change in peripheral sensation, creates a new chain of sensory and motor responses.

The path of an impulse through the nervous system is not linear, from stimulation to sensation to motor response; it is always circular, each motor response in turn providing stimulation which colors the sensations, which alter the subsequent motor responses, and so on and on and on. My own tissues are among the objects that touch my awareness, and my own muscular responses are continually a part of the creation of sensory information about the world that floods my central nervous system. Movement itself is the factor which unites the two halves of my nervous system into a unified relationship of continually mutual reciprocity — "Perception and motor answer are the two sides of the unit behavior."
This is to say that the extent to which I move, and the manner in which I move, have everything to do with what I know about myself and what I know about the outside world.

Movement leads to a better orientation in relation to our own body. We do not know very much about our body until we move it. Movement is a great unifying factor between the different parts of our body. By movements we come into a definite relation to the outside world and to objects, and only in contact with this outside world are we able to correlate the diverse impressions concerning our own body. The knowledge of our body is to a great extent dependent upon our actions.

If I lie motionless for a period of time in a sensory isolation tank, or if I adopt a stress-free and motionless meditative posture, I begin to lose the crisp sense of my physical boundaries, and my mental picture of the spatial relationships of my body parts undergoes bizarre distortions. My feet and hands may seem miles away. My body as a whole may seem incredibly dense and heavy, or large and inflated like a huge balloon. I may feel my physical self dispersing like a gas into the void, or I may feel no connection whatever between my conscious awareness and my living cells.

Such induced hallucinations are often triggered by the disassociation of the sensory and motor elements that are welded together in our normal states of perception. This disassociation can also be accomplished by various drugs, such as the opiates or the hallucinogens, whose pharmaceutical effects disrupt our sensory/motor unity in various ways. In all these situations, the conscious activity of my mind leaves far behind the concrete feedback loops between my nerves and my muscles, and without the solid underpinning of movement correctly correlated with sensation, my thought processes confuse some of the basic distinctions between internal feeling states and objects. The marvelous or hideous phantasmagoras of my imagination take on as much palpable reality as anything else I am experiencing at the moment. The same hallucinatory effects occur in the musically and sensorily suppressed state of sleep.

Movement as the Basis of Perception

So perception is formed on the basis of movement, just as surely and completely as movement is initiated and guided by perception. I have only to begin gently moving my limbs in the water of the isolation tank for the sharp lines of my physical boundaries to leap back into focus; I have only to make a few wriggles and stretches for all of my body parts to reassert their physical relationships in my consciousness.

We do not feel our body so much when it is at rest; but we get a clearer perception of it when it moves and when new sensations are obtained in contact with reality, that is to say, with objects.

Various degrees of friction, stretching, and impact are the only things which build up our sense of tactile reality, and motion is fundamental to all of them. And this is just as true when I am feeling myself as it is when I am feeling other things.
quadriceps is tapped with a rubber mallet just below the knee-cap, and this tap has the effect of a sharp tug on the muscle fibers of the thigh. This sudden change in length of the thigh muscles is registered by the anulospiral receptors, which in turn stimulate in the spinal cord the motor neurons which power the thigh, causing a brief contraction of the thigh muscles which makes the foot jerk forward in a healthy reflex. This automatic contraction has the effect of keeping the thigh muscles at a constant length regardless of outside forces acting upon it, and makes it possible to maintain erect posture in spite of external disturbances.

The components of this arc are like a miniature or primitive nervous system, a microcosm of our nervous system as a whole, a system which "in its simplest form is merely a mechanism by which a muscular movement can be initiated by some change in peripheral sensation." My spindles and their reflex arcs are tiny neural units that monitor and influence motor events that are so continuous and so numerous that they would totally overwhelm my conscious mind. Even if I could keep track of the changing lengths of every one of my millions of muscle cells, I certainly would have no room left to think about anything else.

The Gamma Motor System

The contractile portions of the intrafusal fibers are innervated by motor neurons in the same fashion as are the larger skeletal muscle cells. The intrafusal membrane is contacted by a motor end plate, which stimulates the spindle cell into contracting or fixing its length, or ceases stimulation to allow the cell to be lengthened passively. But the motor neurons which control the intrafusals are altogether separate from the ones which control the skeletal muscles.

The skeletal motor neurons are larger in diameter, with their own vertical tracts through the length of the spinal cord, and end their paths near the summit of the brain, in the motor cortex. They are called alpha motor neurons. The motor neurons for the intrafusal fibers, in contrast, are smaller in diameter, have their

7-8: The simple stretch reflex created by spindle reflex arcs. When the patellar tendon is tapped with a mallet, it has the effect of sharply tugging upon the attached extensor muscles, the quadriceps. This sharp tug fires the anulospiral receptors, which in turn fire the motor neurons in the spinal cord associated with the quadriceps, causing them to contract quickly. As a result, the knee jerks, indicating a healthy reflex.
Gamma motor neurons stimulate the intrafusal muscle fibers, and alpha motor neurons stimulate the skeletal muscle fibers. They are each a completely different motor system; the ascending gamma paths terminate in cell bodies in the brain stem, while alpha paths ascend all the way to cell bodies in the motor area of the cerebral cortex. One third of our motor neurons are gamma.

We have, then, two separate motor systems within us. One of them, the alpha system, originates in the cortex, is closely associated with conscious sensations in the sensory cortex, operates the skeletal muscles, and is responsive to my conscious commands to lift an arm, take a step, and so on. The other system, the gamma, originates deep inside the older part of the brain, is associated with lower sensory centers that produce no conscious sensations, controls the lengths of my intrafusal fibers, and functions primarily beneath the levels of my conscious awareness.

These two systems are linked together at their peripheries by the anulospiral receptor, which wraps the middle of the intrafusal fiber and synapses in the spinal column with its alpha partner. And because of these spinal reflex arcs, any impulse and movement initiated by one of the systems necessarily triggers an immediate reciprocal impulse and movement in the other, since the anulospiral receptor is stretched or compressed in either case.

The significance of these two motor systems and their sensory interconnections will become clearer as we proceed to examine their functional relationships. The fact that this significance is considerable is strongly hinted at by the sheer size of the "hidden" gamma system: As it turns out, fully one third of the motor neurons in the human body are gamma.