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Journey to the Center of the Mind

I have shown throughout this book that many brain regions are involved in the maintenance of the self and hence it is nothing short of miraculous that the self as a coherent entity exists at all. Nonetheless, the self is highly integrated and may remain so even after serious physical disruption. Consider patients like Sonia with severe hydrocephalus and Seymour who had a frontal lobotomy. Both of these patients had preserved egos in the presence of significant alterations in their brains. Further, the patients with split brains under most circumstances have preserved mental unity despite the division of their hemispheres. This raises an important question: How does the intact brain, a brain that has no damage, maintain mental unity? How do the many regions of the brain create a coherent self? This is the question I will consider next.

How Does a Distributed Brain Create a Unified Self?

The problem of the unity of the self and individual consciousness seems remarkable when one considers the fantastic diversity and multiplicity of the brain at the microscopic level. Observation of brain matter reveals millions and millions of individual neurons that make up the structures and regions of the brain. For example, it is estimated that in the cat there are ten to fifteen different brain regions devoted to visual function alone. Add to this five areas that are involved in touch sensation and as many as eight cortical areas that are involved in audition.[1]

More evolved species have an even greater number of functionally distinct cortical regions than the cat. In the monkey, for example, there are somewhere between twenty and forty visual areas. In the human being, there is an even greater number of differentiated visual areas in the brain. Van Essen, Anderson, and Felleman suggested that there are thirty-two visual cortical areas.[2] Kaas approximates that in fact there may be over a hundred different human neocortical regions in all![3] These estimates do not include the numerous subcortical sensory processing regions in the human brain, which initially receive the incoming sensory stimuli that will be later processed in the cortex. From these investigations, it is apparent that we have numerous separate regions of the brain that need to be linked to one another in a coherent fashion for optimal functioning. Exactly how these areas of the brain are connected continues to be a vigorously investigated topic in cognitive neuroscience today.[4]

Despite the diversity of the neuroanatomical regions of the brain, the fact remains that the normally intact brain functions to produce a unified "*I*." We experience one integrated sensory world and a single integrated self and a unified ego. But when the brain is examined neuroanatomically, we do not see a unified, homogeneous whole akin to the subjective experience that constitutes a self. We observe only a multitude of independent neurons and a host of brain structures that appear to possess a very different "grain" from the seamless self. How is it then that personal consciousness subjectively seems unified from an "inside" personal perspective for each of us when the brain is structurally diversified?[5]

Descartes' Dilemma

Obtaining the answer to this question has become a central focus in current research on the brain, but it does not represent a *new* problem. Rather, it is an old and yet-to-be-solved problem. Interest in the dilemma of mental unity goes all the way back to the seventeenth-century philosopher René Descartes (1596–1650). Descartes sometimes is considered the first "modern" psychologist, and I would concur with this judgment.[6] Descartes was also the grandfather of the mind/brain theorists, and he was among the first scholars to consider the puzzling fact of the unity of mind from both philosophical and biological perspectives.

For Descartes, the unity of the mind was a logical extension of the oneness of the soul. The soul was composed of its actions and passions, the latter encompassing its perceptions. Descartes reasoned that there were clear differences between the brain on the one hand, and the mind or soul on the other. He correctly identified the brain as a palpable organ with length, breadth and an exact spatial locus within the body. Furthermore, as is the case with all matter, he realized that the brain could be broken into parts. The soul, in contrast, is intangible and indivisible.

> and because it is of a nature which has no relation to extension, nor dimensions, nor other properties of the matter of which the body is composed, but only to the whole conglomerate of its organs, as appears from the fact that we could not in any way conceive of the half or the third of a soul, nor of the space it occupies and because

> it does not become smaller owing to the cutting off of some portion of the body, but separates itself from it entirely when the union of its assembled organs is dissolved. (Descartes, 1649; I: XXX)[7]

Descartes believed that the brain was composed of parts or structures, each performing a unique function. It was also apparent to Descartes that the mind, the self, and the soul were whole entities derived from a person's internal or "inside" point of view. Put another way, the unified appearance of the self from a subjective point of view could not be reconciled with the objective divisible reality of the brain. These differences between mind and brain led Descartes to his famous theory that we now know as Cartesian Dualism, the belief that in the world there are two kinds of substances: the physical (res extensa), consisting of things that have material characteristics; and the mind or thinking substance (res cogitans), which is indivisible and hence nonmaterial.

Descartes reasoned that there must be a way for the unified mind and the immaterial "soul" to interact with the material brain. He decided that the pineal gland was a likely candidate to serve as this material liaison between brain and soul. He reasoned that the pineal gland's single midline position in the central nervous system appeared to make it ideally suited to pull together the two hemispheres of the brain to create a single and unified mind (Figure 7–1). In the following quotation, Descartes explains why he chose this relatively inconspicuous structure for such an important role:

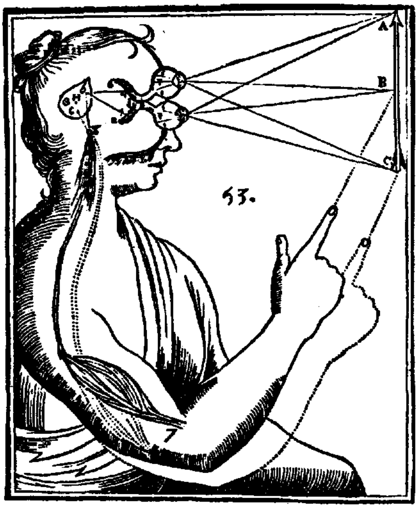

Figure 7-1.
Descartes' conception of the unity of the mind shows the converging point of the mind and the body at the only unpaired structure that Descartes could locate–the pineal gland in the center of the brain. The pineal gland is the teardrop-shaped structure in the center of the head. Descartes believed that the pineal gland was the seat of the soul.

> The reason that persuades me that the soul cannot have any other place in the whole body than this gland, where it immediately exercises its functions, is that I consider that the other parts of our brain are all double so that we have two eyes, two hands, two ears, and, finally all the organs of our external senses are double; and that inasmuch as we have only one solitary and simple thought of one single thing during the same moment, it must necessarily be that there is some place where the two images which come from the two eyes, or the two other impressions which come from a single object by way of the double organs of the other senses, may unite before they reach the soul, so that they do not present to it two objects instead of one. It can easily be conceived how these images or other impressions could unite in this gland through the mediation of the spirits that fill the cavities of the brain. There is no other place in the body where they could be thus united unless it be in the gland.[8]

Sherrington Ponders the Mind's Eye

We now know that the human pineal gland is actually a neuroendocrine organ that plays no role whatsoever in neural transmission or consciousness. One might excuse Descartes' mistake as a result of the limited neurological knowledge of the time. However, hundreds of years later, at the start of the twentieth century, when a good deal more was known about the nervous system, Sir Charles Sherrington, the father of modern neurophysiology, still wondered how the brain produces a unified mind.

Sherrington asked a question similar to those posed by Descartes, but that instead involved the integration of the components of the visual system: How is it possible that there is a "singleness" of normal binocular vision when either eye alone is able to generate a separate mental image?[9] Sherrington was aware that we are capable, under certain circumstances, of being aware of *simultaneous* independent images generated by each eye. If one places, for instance, a red glass over one eye (the so-called Red Glass Test), slight deviations in the axes of the eyes can be made apparent such that the axes do not "line up" properly. The patient then experiences two independent visual images, one colored red and the other normal. In the same way, when the direction of each eye is not properly aligned, as when we are drowsy or have had one too many martinis, a person may become aware of two visual images and then we say we are "seeing double" (Figure 7–2).

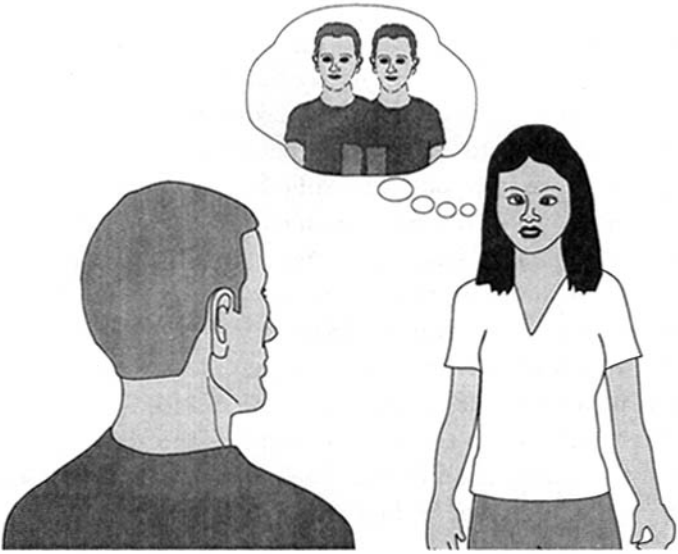

Figure 7-2.
The brain under normal circumstances does an excellent job of keeping vision unified. If the axes of the eyes are not properly aligned, the retinal images from the two eyes can be disconnected, and the person "sees double."

Except for unique circumstances, like the Red Glass Test when simultaneous independent images by each eye can be generated, there typically is a remarkable unity to the visual system. Sherrington noted that under normal circumstances:

> Our binocular visual field is shown by analysis, to presuppose outlook from the body by a single eye centred at a point in the mid-vertical of the forehead at the level of the root of his nose. It, unconsciously, takes for granted that its seeing is done by a cyclopean eye having a center of rotation at the point of intersection just mentioned.[10]

Simply put, the mind seems to have a visual synthesis point originating somewhere smack between our eyes and behind the top of our nose, as if there were a single cyclopean eye looking out from this point on the forehead (Figure 7-3). It is from this central–and single–vantage point that we experience the world visually as a coherent entity.

The problem is, needless to say, that we do not have such an eye located in the middle of the brain; rather, the brain works in a fashion such that we *seem* to have a central, cyclopean eye. Under normal circumstances, we experience a unified visual world within a single integrated self. But where

Figure 7-3.
Although we have two eyes that possess overlapping visual fields, the brain creates a single "mind's eye" that seems to be located at a point somewhere between and behind the actual eyes.

does the unified visual field come from? How do the material parts of the brain involved with vision combine to bring this novel unified visual field into being? And where is the "mind's eye" physically located? Can it even be said to have a physical location?

One might suppose that the brain could achieve visual and by extension mental unity if every part of the brain that contributes to the self goes to a central place in the brain where it can be organized into a coherent whole. But, as Sherrington pointed out, there is no "psychic pineal gland":

> Where it is a question of "mind" the nervous system does not integrate itself by centralization upon one pontifical cell. Rather it elaborates a million fold democracy whose each unit is a cell.[11]

Sherrington was confronted with a paradox. On the one hand, he believed that the mind is able to integrate information from both eyes and create a single visual image in the mind from a particular vantage point behind and between the eyes. On the other hand, Sherrington could not find, or even imagine, a particular place, or "pontifical cell" in the brain where this integration occurs. Sherrington consequently arrived at a solution to the mind-brain problem that was similar to Descartes' solution: He asserted that the integration of the mind and the body is *mental* not *physical.*

Was Sherrington correct? Is there reason to believe, based on our current knowledge of the operations of the visual system, that the mental and physical worlds are two separate domains? The questions raised by Sherrington about the visual system parallel those asked about the neurology of the self. Just as the cyclopean eye is built up from the inputs of the two eyes, the self is created from the unification of many parts of the brain. If it can be shown, as asserted by Sherrington, that within the visual system there really is a split between the mental and physical, this finding would have profound implications for the neurology of the self. If the "mind's eye" proves to be a *mental integration but not a physical reality*, this could mean that the unified self is an immaterial entity as well. It is important therefore to understand how the brain creates visual unity in order to understand how the brain creates mental unity.

Mental Unity and the Visual System

Modern neuroscientists, unlike Descartes and Sherrington, have at their disposal an enormous amount of information about the operation of the visual system. The visual pathways can be thought of as streams of information flowing from the eye to the brain.[12] Vision begins at the eye's retina that has millions of rods and cones, the specialized cells that respond to light. These specialized cells enable the eye to transform light energy into electrical neural signals for processing later on in the visual regions of the brain. Each cell of the retina responds to a particular area of the visual world and this region of space that each cell monitors is called the cell's *receptive field.* For instance, a single retinal cell responds most strongly when a tiny circular light in a particular point in space stimulates a specific point on the retina within that cell's receptive field. The receptive field of each retinal cell is quite small, and somehow the brain must build up whole, and hence unified, mental representations of objects from these minuscule and discrete points of contact with the world.

After many complicated intermediary steps, the stream of incoming visual information eventually reaches the brain for additional processing. The brain area known as V1 is the primary cortical area to receive visual information. In the 1960s, Torsten Hubel and David Wiesel, in work that led to their receiving the Noble Prize in 1981, demonstrated that cells in V1, which they called *simple* cortical cells, responded not to points of light–as in the retina–but to a thin bar of light.[13] Hubel and Wiesel questioned how a *single* neuron in the brain could respond to a *line* in the world. They reasoned that if a line of adjacent firing cells–each responsive to an individual point of light–converged on a single simple cortical cell further along the processing stream, that single cortical cell could "add up" the points of light that each lower order cell had responded to. In this way, a *single* higher order cell could respond to a *line.*

Hubel and Wiesel further traced the visual processing stream for a line in the brain and found that multiple simple cortical cells converged on other single higher order cells to create what they called *complex* cortical cells. These complex cells displayed even more complicated properties than the simple cells: they converged on single neurons to create *hyper-complex* cells with increasingly specific and complex response properties. The model of Hubel and Wiesel is hierarchical in that simple cells lower or earlier in the neural processing chain create cells of ever-increasing complexity higher up on the neural hierarchy.

In this schema, the progression from simple to complex to hypercomplex cells is an example of what the visual neurobiologist Semir Zeki terms "topical convergence."[14] This is the process whereby many lower order, simple visual cells simultaneously *converge* on a smaller number of higher order complex cells. Topical convergence ultimately produces advanced "higher order" cells that possess amazingly specific response properties. These very complex cells, or neurons, are found in the inferior temporal cortex, way up the neural hierarchy and far "downstream" from the simple cells found early in the primary visual region. Higher order visual cells respond preferentially to highly specific and complex stimuli such as hands or faces. Some of these neurons respond best to the frontal view of a face and others to a side view. Neurons of this type led to the somewhat fanciful notion of the "grandmother" cell, a cell so specific that it fires only to the vision of one's grandmother![15] Cells of that degree of specificity do not exist, but it is true that the farther along a sensory processing stream that one looks, the more specific a cell's response characteristics become (Figure 7–4).

The creation of a hypercomplex cell like a face cell poses a problem for mental unity. In the process of creating higher order cells, like the hypothetical "grandmother cell," *the receptive fields of these cells increase in size.* Although a retinal cell early in the stream monitors a tiny specific point in the visual field, a hypercomplex cell such as a face cell will react to a face that appears almost *anywhere* in the person's entire visual field. While the cells early in the visual stream have small receptive fields and "know" where each line of the face is, these early cells do not "know" that a given line is part of a face. They do not have knowledge of the "big picture" of the face that will emerge later on in the processing stream. The face cells, on the other hand, "know" there is a face, but due to the process of topical convergence, these cells don't know where the face is located in space. Cells of the brain project higher and higher in a hierarchical fashion in order to code for increasingly specific complex and abstract properties, but information coded by cells earlier in the process

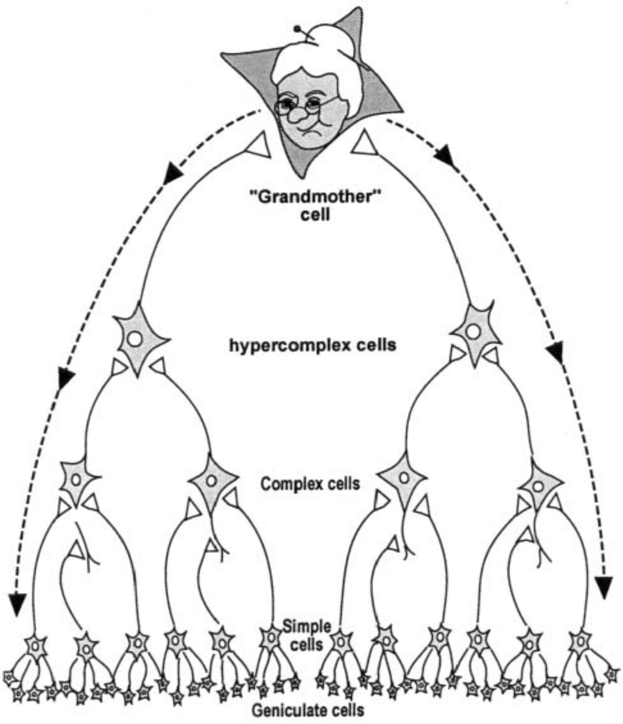

Figure 7-4.
Converging pathways from simple to complex cells, and then from complex to hypercomplex cells, create neurons with very specific and abstract response properties. If the process continued up the visual hierarchy, one could imagine the creation of the so-called grandmother cell that responds only to the face of one's grandmother.

is not and cannot be lost in awareness.[16] As Zeki observes, cells comprising *both* the early and the late stages of the visual processing stream must make a unique contribution to consciousness.[17] In this way the conscious mind is "spread out" across the activity of the many neurons that make up different regions of the brain.

The Cartesian Theater and the Binding Problem

If consciousness generally is distributed throughout the brain in this manner, then the question How is the self integrated? remains. Let us say, for the sake of argument, that all the cells that make a contribution to the conscious mind (including cells early and late in a sensory processing stream) *do* congregate in a central place in the brain. And let us further assume that our conscious mind is the product of the activity of these cells, and that this central place in the brain is the "pinnacle" of the mind and the self. The philosopher Daniel Dennett, in his book *Consciousness Explained*, dismissed the notion that all the neurons involved in consciousness somehow project their activity to a single brain region.[18] Dennett argued that this sort of reasoning required what he has called a "Cartesian Theater," an imaginary place in the brain where all conscious activity could be presented on an inner mental stage or screen for simultaneous viewing. Dennett named his "theater" after Descartes because it was Descartes who first suggested that the mind could be unified within a single place in the brain–namely, the pineal gland.

There are two major reasons why the idea of the Cartesian Theater doesn't work. As Dennett points out, and we have already discussed, the Cartesian Theater simply doesn't exist. There is no place in the brain in which all the brain's activity converges on "one pontifical cell." There is an additional problem with the idea of the Cartesian Theater. If we suppose that all brain activity contributing to consciousness is flashed on a mental "big screen TV" for simultaneous viewing, who is in the audience? This idea implies that there has to be an "inner homunculus"–a little person inside the head–who possesses the mind's eye and who is watching the show. But now we are left with another problem. To whom does this homunculus report? Yet another homunculus? With this line of reasoning we are inevitably led to an infinite series of homunculi and to a process that leads to nowhere (Figure 7–5).[19]

Scientists who study how the brain creates consciousness are particularly interested in the "binding problem."[20] Binding refers to the manner in which visual percepts are unified when cells located in different parts of the brain code for specific attributes. For example, color is processed in one part of the visual system and visual form in another. The brain needs a way to bind the correct shapes with the correct colors to form objects or images even though these two visual attributes are processed in different brain regions. What we have said about the visual system regarding its integration process becomes even more complex when the brain must coordinate features of a stimulus from multiple sensory domains, such as an object having both visual and auditory features. How are the color, shape, and honking horn of a red Corvette integrated into a unified perception? How does the brain bind the color red and the honking horn to the car, and the color brown and the barking to the dog it passes, and not the other way around? When we considered just a visual stimulus, the binding process involved only the visual centers of the brain. Now when considering the stimuli honking red Corvette or brown barking dog, binding must occur in both visual and auditory centers that are located in even more widely distributed areas of the brain.

Figure 7-5.
If the mind is created by a series of ever more complex grandmother cells, but the grandmother cells don't end up in one place, how is mental unity possible? It would appear that we need a Cartesian Theater where all the brain's parts can be simultaneously viewed by an inner homunculus. The difficulty with this type of reasoning is that it leads to an infinite regress of homunculi.

The brain must find ways to bind percepts together that are represented across separate brain regions. So how does the brain do this?

One way to explain binding in the visual system is that the brain uses synchronized oscillations to unify perception.[21] According to this account, the various neurons that are responsive to different visual attributes of a single object are bound together in awareness because they fire together in a synchronized fashion. The neurons coding for the shape, location, and color of the Corvette are all firing at one and the same frequency, and the attributes of the dog are firing at another frequency. A particular object then is represented coherently in the brain and can be distinguished from other objects. In his book *The Astonishing Hypothesis,* the Nobel Laureate molecular biologist-turned neuroscientist Francis Crick suggested that synchronized neuronal firing in the 35 to 75 Hertz range "might be the neural correlate of visual awareness."[22]

Another explanation for binding in the visual system, and mental unity in general, was offered by Nobel Laureate Gerald Edelman. Edelman also considered the problem of unification as the key to understanding consciousness. In his book *The Remembered Present: A Biological Theory of Consciousness* he posited that re-entrant cortical integration (RCI) represents the major integrative factor in the brain's construction of a unified consciousness.[23] According to Edelman, RCI is the back-and-forth signaling from multiple brain areas that allows segregated and distributed brain areas to "pull together" integrated representations. In this framework, Edelman contended that visual consciousness is unified, but that there is no need for all of the brain's inputs to end *physically* in the same place.

In fact, it is likely that the brain uses many mechanisms to perceptually bind objects in awareness, including convergence, synchronized oscillations, and re-entry. Nonetheless, whatever mechanisms the brain uses to bind objects in perception, some important questions remain. If consciousness is distributed across billions of individual neurons that are located in innumerable brain regions at different hierarchical levels of the nervous system, does it follow that each of these neurons individually "possesses" consciousness? And even if these neurons are networked together, is there something physically unified in the brain that has the same grain as the unified mind? It appears that there is still a "gap" between the objectively distributed and divisible brain and our subjective experience of a coherent and seamless "inner eye."

My reason for considering perceptual unity here has been to point out that the enigmas of visual and mental unity and the puzzle of the unification of the self that are addressed throughout this book are essentially the same: *If there is no area in the brain where all the regions that contribute to the self physically "come together," then how do we exist as whole, integrated, unified persons?*

The Ghost in the Machine

Before answering this question in the next chapter, I want to consider a similar and equally important problem for the unification of the mind and the self, and that is the unification of *action*. Just as the unification of the visual system contributes to our sense that we are unified beings, our ability to produce unified actions is essential to our feeling of wholeness as a person. When we act, we feel there is a unified self that is the source of what we do. But the *motor system*, like the visual system, is composed of millions of individual neurons. These neurons are organized to produce exquisitely integrated and unified actions, but there is no region or point in space at the top of the motor hierarchy at which we can locate the source of this unity.

Consider a simple action such as raising your arm. Suppose you say to yourself, "I will now move my arm" and you raise your arm. As you do this, you will experience an "inner I" as the source of that action; the "I" makes the conscious decision and exercises the "will" to move the arm. Suppose I, as your neurologist, search for the *source* of that "will" somewhere in your brain. I will find that there is no central, integrated, and unified physical locus that is the source of that action. There are no "commander-in-chief" neurons that I can identify in your brain as your "I" that ordered the action. There is no singular locus or top of the motor system, no "ghost in the machine" as the philosopher Gilbert Ryle famously put it, which can serve as the source of our unified "will."[24]

While looking for a way of pictorially representing the hierarchy of action, in a format similar to the depiction of the hierarchy of perception as shown in Figure 7–4, I came across a wonderful old book by the ethologist N. Tinbergen. In *The Study of Instinct,* which he wrote in 1951, Tinbergen analyzed a simple example of motor behavior, the instinctive behavior of the male three-spined stickleback fish.[25] I have fond memories of this fish, because it was a favorite subject of my psychology courses in college. Tinbergen described the levels of motoric behavior of this fish in a hierarchical fashion (Figure 7–6).

At the lowest level of this hierarchy is the single motor unit. A single motor unit consists of a single motor neuron and all the individual muscle fibers to which it is connected. It is the action of the muscle fibers that enables the fish to swim. At this level of the nervous system, the activity of a single motor unit is simple and undifferentiated. Any given

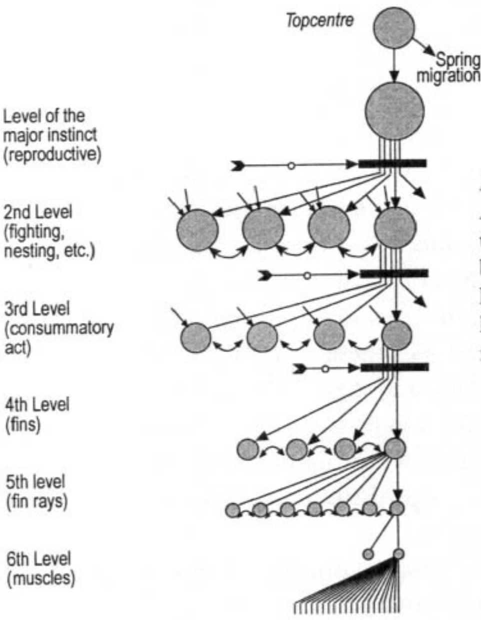

Figure 7-6.
An analysis by Tinbergen of the behavior of the stickleback fish. Tinbergen saw the behavior as hierarchical, with the highest level of the hierarchy the instinct and the lowest levels the individual muscles of the fish's fins.

motor unit will fire in the same fashion for each action that the fish takes, regardless of what that action is. When a neuron is activated as when the fish withdraws a fin in response to a jab by a piece of sharp coral or is engaged in a mating ritual, it does not matter a whit to that particular neuron what the rest of the fish is doing at the moment or why it is doing it. That neuron is just "following orders." The control for any action at the lower levels of the hierarchy comes from the higher levels of the nervous system. To find the source of the control, we must follow Tinbergen's hierarchy upward from single motor units, to the movement of entire muscles, and from there to the control of fin rays and further to fins, etc. Finally, at the top of the hierarchy, it is instinct that dictates control over the coordinated actions that make up the repetoire of the fish's motor behaviors.

Tinbergen's scheme appears pyramidal in shape, with many parts at the bottom of the pyramid converging on a single element at the top. But, just as in the perceptual hierarchy that appears to lead to the "grandmother cell" in the visual system (Figure 7–4), there is no single cell or brain region in reality that sits atop this motoric hierarchy. The instinct originates from the highest brain regions of the fish, and surely some particular areas of the fish brain are more necessary for instinctual behaviors than others. But *this instinct has no unified spatial locus in the brain.* Even though the instinct is unified in the behavior of the fish, it is not materially unified in the fish brain. The brain locus of an instinct, and hence the source of the unified action of the fish, is distributed across large regions of the fish brain.

We can also consider the hierarchical organization of human speech. If we trace the control of our speech, at the lowest level of control, there are the neurons connected to the individual muscles of the lips, tongue, face, and so on. The control of these neurons is located within the control of the joints, etc., whose control we can ultimately trace into the brain. What sits atop the hierarchy of this complicated behavior? If we look in the brain for the areas that control speech, we know first of all that the frontal portions of the left hemisphere are particularly important for the production of fluent speech, so that this area must be involved in the control of speech. We also know that the posterior portion of the left hemisphere is critical for the knowledge of the words we use in speech, and that this region of the left hemisphere is also necessary for the comprehension of speech and for self-monitoring as we listen to ourselves speak. We therefore must include this region in the act of speech production as well. We also know the right hemisphere is important for creating emotional inflection in speech production, so include this area too.

And if you gesture with your hands as you speak, we need to include the motor areas of both sides of the brain as a part of the overall act of expressing oneself. It is clear that vast areas of the brain are involved in the complicated act of speech production, yet somehow when we "will" to speak, the entire act is *unified* into a whole and coordinated behavior. But exactly how? Or by whom? Or what?

Once again, as when we considered the source of visual unity, when we search for the inner source of the center of the "will," we find ourselves at impasse. Just as there is no "pontifical neuron" sitting atop the perceptual hierarchy, there is no single brain region creating and controlling our actions and intentions. There does not appear to be any material "top" to either the perceptual or motor hierarchy. We cannot put a material "self" or "ego" at the top of any hierarchy. From the standpoint of the self, we surely experience ourselves as a unified person "in here" inside ourselves; we think that when we act, a unified self "wills" such actions. Yet our neurology and neuroscience can find no "ghost in the machine," no homunculus, no inner unified "biological soul" as it were. Where is the self then? What is it? What is its biological reality? Are we destined (doomed?) to a Cartesian Dualism, or is another explanation for the unity of the self possible? A new model, a new way of thinking about the self and the brain, is needed if we are to solve this 300-year-old problem.