# Selectivity, Integration, and the
# Psycho-Neuro-Biological Continuum

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An important insight derived from Kant about the workings of the mind is that conscious activity involves both the selection of relevant information, and the integration of that information, so as to form mental coherency. The conscious mind can then utilize this coherent information to solve problems, invent tools, synthesize concepts, produce works of art, and the like. In this paper, it will be suggested that just as biological processes, in general, exhibit selective and integrative functions, and just as visual integration performs the function of selecting and integrating visual module areas, so too, consciousness emerged as a property of the brain to act as a kind of meta-cognitive process that selects and integrates relevant information from psychological modules. The upshot is to establish a psycho-neuro-biological continuum by suggesting that the conscious psychological properties of selectivity and integration are possible because of similar properties that other neurobiological and biological processes exhibit.

Keywords: selectivity, integration, consciousness

When we are engaged in conscious activity, the mind actively does something with the information that is provided to it. The fundamental insight derived from Kant (1929), and reiterated by numerous philosophers, psychologists, neuroscientists, and other thinkers is that consciousness is an active process involving the selection of relevant information, and the integration of that information, so as to form mental coherency (e.g., Gardner, 1999; Husserl, 1960; Rorty, 1981; Sternberg, 2001; Tononi and Edelman, 1988; Velmans, 1992). The mind then can utilize this coherently organized information to solve some problem in the environment (Rock, 1984; Rosch, 1981), construct a tool (Isaac, 1986; McNabb and Ashton, 1995; Wynn, 1993), be creative (Arp, 2005; Finke, Ward, and Smith, 1992), synthesize wholly disparate concepts (Holyoak and Thagard, 1995; Koestler, 1964), or

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even generate meta-theories and metaphors (Fauconnier and Turner, 2002; Goguen and Harrell, 2004). Kandel, Schwartz, and Jessell (2000) bolster Kant's insight when they claim that perception "organizes an object's essential properties well enough to let us handle the object" (p. 412). Drawing directly on Kant's insights, they claim further that our perceptions "are constructed internally according to constraints imposed by the architecture of the nervous system and its functional abilities" (p. 412). Consider Figure 1 below. We immediately recognize the space in the middle as an octagon. However, the reason why we can seems to be because our visual perception is constructive. The mind brings something to the diagram and *fills in the blank* (literally!), in generating the image of the octagon (cf. Huttenlocher, 1968; Kanizsa, 1976, 1979; Sekuler and Blake, 2002).
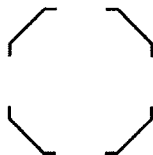
Figure 1: A fill-in-the-blank octagon.

In this paper, Kant's fundamental insight will be proffered, and it will be suggested that the conscious psychological properties of selectivity and integration are possible because of similar properties that other neurobiological and biological processes exhibit. For example, visual processes actively select and integrate the information concerning the lines and spaces in Figure 1 above, so as to produce a coherent picture of the octagon. So too, consciousness has emerged from neurobiological processes, and actively selects and integrates information from mental modules so as to produce coherent psychological phenomena. Just as biological processes, in general, exhibit selective and integrative functions, and just as visual integration performs the function of selecting and integrating visual module areas, so too, consciousness emerged as a property of the brain to act as a kind of meta-cognitive process that selects and integrates relevant information from psychological modules.

## The Biological Basis of Selectivity and Integration: Organisms as Hierarchies

Many biologists and other thinkers are aligned with Mayr (1996) in thinking that organisms are "hierarchically organized systems, operating on the basis of historically acquired programs of information" (p. 103; e.g., Audesirk,

Audesirk, and Beyers, 2002; Bogdan, 1994; Collier and Hooker, 1999; Csányi, 1996; Eldredge, 1995; Gould, 2002; Lycan, 1995). What exactly does this mean? An organism can be defined as a *hierarchically organized living system made up of components that are engaged in processes constituting coordinated subsystems, with the product of these processes and subsystems being homeostasic relative to their operations, producing the overall homeostasis of the organism.* As a *system*, an organism is a unified entity that is explainable in terms of the properties of its components, the interactions of these components, and the overall coordination of these components. As a *living* system, an organism has to be made up of at least one cell, the basic unit of life. To understand what it means for an organism to be a *hierarchically organized* living system, we need to investigate the properties of the components of this kind of system. These properties include the following:

A. *Internal–Hierarchical Data Exchange*
B. *Data Selectivity*
C. *Informational Integration*

However, before investigating internal–hierarchical data exchange in an organism, it is necessary to explicate further the words *component* and *homeostasis* utilized in the above definition of an organism.

The word *component* is a term that can be used analogously to refer to either a part of a process, a part of a subsystem or a part of a system. In the most general of terms, an organism is a unified living system made up of subsystems. In turn, these subsystems are made up of processes, and these processes are the activities in which the components are engaged. The components of an organism range from the organelles performing processes in a cell, to cells performing processes in an organ, to organs performing processes in a subsystem, to subsystems performing processes in the whole system itself, i.e., the organism. So, for example, the respiratory subsystem works with other subsystems in an organism like a dog to maintain its life. The respiratory subsystem would be considered as one component of the entire dog, envisioned as one whole system; the lung would be considered as one component of the respiratory subsystem of the dog; lung cellular tissue comprising one of the lobes of its lung would be considered as one component of the lung; and the particular kind of cell that comprises lung tissue is made up of organelles, the basic components of cells.

Homeostasis refers to the *relatively constant or stable coordination of functioning among the components in the organismic hierarchy, given the interaction of these components with environmental pressures internal to and external to the organism.* Of course, there are environments exerting pressures upon the subsystems and processes internal to an organism, as well as environments exert-

ing pressures upon the organism as a whole that are external to it (Brandon, 1984, 1992). The components that make up an organism, as well as the organism itself, are able to respond effectively to the ever-changing environmental pressures by adjusting and re-adjusting their activities so as to continue their respective operations with a degree of stability. When a subsystem or process in an organism is operating with a degree of stability, *despite* environmental pressures — e.g., when the cell wall *actually* performs the activity of allowing nutrients into the cell, or when a heart *actually* performs the activity of pumping blood, or when the body of an animal *actually* cools itself through perspiration because its temperature has been raised above a certain degree — it is said to be functioning properly.

We can draw a distinction between *particularized homeostasis* and *generalized homeostasis*. Particularized homeostasis refers to the end product of the proper functioning of the *particular* processes and subsystems in an organism being the relatively constant coordination among the components that make up the processes and subsystems, given environmental pressures that are *internal* to the organism. Generalized homeostasis refers to the *overall maintenance of the life* of an organism being the result of the proper functioning of the processes and subsystems, given environmental pressures that are *external* to the organism. The overall homeostasis of the living system is maintained because homeostasis is also maintained at the levels of the subsystems and processes.

If the various processes and subsystems of an organism are functioning properly in their internal environments — thereby producing particularized homeostasis — the organism is able to live its life effectively in some external environment. This proper functioning that yields internal homeostasis takes place at levels in the hierarchy of the organism ranging from the coordinated activities of organelles in the cell, to cells performing coordinated processes in an organ, to organs performing coordinated processes in a subsystem, to subsystems performing coordinated activities in an organism. So, taking our example of the dog: the dog is able to live its life in some external environment precisely because of the overall relatively constant coordination of the subsystems in its body; in turn a particular subsystem, like the respiratory subsystem, functions properly because of the relatively constant coordination of cellular processes; and the cells themselves function properly because of the relatively constant coordination among the various organelles.

The subsystems and processes of an organism can be understood as functioning at various levels of operation from lower levels to higher levels. The determination of a subsystem as existing at a certain level depends upon the way in which the processes of the subsystem operate, and in turn, the way in which the subsystems operate in the organism as a whole. Lower-level processes operate in certain ways, and form the basis for higher-level processes and subsystems. In turn, higher-level subsystems and processes are comprised

of lower-level processes, and utilize the information from these lower-levels to perform their own operations. In this sense, along with Audesirk et al. (2002), Lycan (1995), and Salthe and Matsuno (1995), we could say that higher-level subsystems are the phenomena that literally *emerge* from lower-level subsystems and processes.
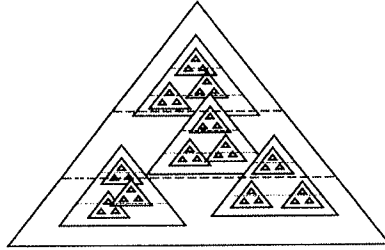


Figure 2: A hierarchically organized system.

The organism can be conceptualized as a hierarchical organization whereby levels of operation, in the forms of subsystems and processes, function inter-dependently with one another in this unified system. A schematization of this hierarchical system is shown in Figure 2 above. The organism is represented by the large partitioned triangle that contains the smaller partitioned triangles within it: the biggest triangles within the one large triangle represent subsystems; the smaller triangles within those subsystems represent processes; the smallest triangles within those processes represent components of processes; the partitions represent levels of operation. Some of the triangles overlap, signifying that the subsystems are interdependently related to one another. For example, in a hierarchically ordered system like the mammal, the nervous (sub)system is dependent upon the respiratory and circular (sub)systems, primarily for a process of oxygen transfer to the nerve cells and brain cells of the nervous (sub)system. At the same time, the processes of the respiratory and circular (sub)systems are dependent upon the processes of the nervous (sub)system, found specifically in the medulla of the brain, for their activities.

Consider that an organism like the human body is a complex multi-cellular entity made up of levels of independently organized entities that perform certain operations. These organized entities are hierarchically arranged from organ systems (e.g., the nervous system), composed of organs (brain, spinal cord, etc.), that are composed of tissues (nervous tissue), which are composed of cells (neurons, glial cells), each of which is composed of organelles (mitochondrion, nucleus, etc.), that are composed of organic molecules

(carbon, nitrogen, oxygen, DNA, etc.). Each of these entities functions such that the operations at the lower levels contribute to the emergence of entities and their operations at the higher levels: because of the activities of organic molecules, it is possible for organelles and their attending activities at a higher level to emerge; and because of the activities of organelles, it is possible for cells and their attending activities at a higher level to emerge; and so on.

The metaphysical view being endorsed here is known as *emergentism*. According to this view, entities, properties, or substances arise out of more fundamental entities, properties or substances and yet, are not wholly reducible to them (Broad, 1925; Hasker, 1999; Kim, 1999; O'Connor, 1994; Zylstra, 1992). Emergentists deny the general principle that the whole can be explained fully in terms of the parts, and so their view is contrasted with *reductive materialism*. According to reductive materialists, there are really no entities, properties, or substances that arise out of more fundamental ones since, once the more fundamental ones have been described, that is all there is to the description of an entity, property or substance.

Metaphysical reductive materialists attempt to reduce entities, properties, or substances to their lowest common denominator, as it were, and this usually means a description in terms of physico-chemical entities, properties, or substances and their attending laws or principles (see O'Connor, 1994). So for example, because the makeup of the cell and its functioning depends upon physico-chemical entities and their attending laws, according to a reductive materialist the cell *just is* these physico-chemical entities and their relations. Issues surrounding metaphysical reductionism and emergentism are particularly poignant when describing organisms. This is so because it would appear that biology has its own set of laws and organisms have their own sets of properties that, despite being dependent upon physico-chemical laws and properties, are non-reducible to them (see Mayr, 1969, 1996). In biological matters, an anti-reductionist's use of emergence accepts or implies that biological properties or processes may emerge that are not reducible, even in principle, to physico-chemical properties and processes. So, the issue thinkers confront when trying to give a description of organisms and the functioning of their components can be put in the form of a question: Has the biologist given us a description of organisms and the functioning of their parts that is so basic as to be unachievable by a physico-chemical description? In other words, in describing organisms and the functions of their systems and processes, does the biologist give us something that the physicist or chemist leaves out?

It is arguable that, *starting with the organelles that make up a cell*, and continuing up the hierarchy of components in processes and subsystems of an organism, we have clear instances of emergent biological phenomena. The fundamental reason that these components and their attending processes must be considered as emergent phenomena has to do with the way in which

the components are *organized to do something directly related to the homeostasis of the organism* at the various levels in the hierarchy. Earlier, a distinction was drawn between particularized homeostasis and generalized homeostasis. We saw that because the various processes and subsystems of an organism are functioning properly in their internal environments (particularized homeostasis), the organism is able to live its life effectively in some external environment (generalized homeostasis). Here, the very existence of components and their activities at various levels in the organism's hierarchy is linked to the coordination of such components *so as ultimately to produce generalized homeostasis*. The components of an organism are organized in such a way that the resultant outcome of their processes becomes first, particularized homeostasis, and then, generalized homeostasis. *That* components are organized to perform some function resulting in homeostasis is one feature that marks them out to be novel emergent entities distinguishable from the very physico-chemical processes of which they are composed.

It has been said already that homeostasis first occurs at the basic level of the organized coordination of the activities of organelles in a cell. Researchers like Audesirk et al. (2002), Campbell and Reece (1999), Kandel et al. (2000), and Smolensky (1988) document cellular homeostasis. At this basic level of organelle interaction within the cell, we also would have the first instances of salient emergent biological properties that are distinct from the physico-chemical properties upon which they depend. In fact, *components* of organisms as they have been described, viz., organelles, cells, organs, subsystems — as well as the organism itself — all would be considered emergent entities. Referring to the schematization of an organism as one huge triangle containing smaller triangles that was used in Figure 2, each one of those triangles, from biggest to smallest, represents a biologically emergent phenomenon. Although the organelles themselves are made up of physico-chemical entities, they engage in coordinated kinds of activities that benefit the overall homeostasis of the cell; so too, although kidney cells are made up of organelles — which are made up of physico-chemical entities — the kidney cells themselves engage in coordinated activities that benefit the homeostasis of the kidney, and so on up the hierarchy.

It is arguable that physico-chemical entities themselves are not coordinated in such a way so as to produce homeostatic results; they are not *organized to do something*, or achieve some result *in this manner*. Further, physico-chemical entities are not organized in hierarchical ways such that we could say they are engaged in particularized homeostatic processes contributing to a generalized homeostasis. It seems that something is left out of the description of an organism if we say that, for example, a dog *just is* a mass made up of chemical properties having certain kinds of bonds, subject to laws of electromagnetism, gravity, etc. This kind of description works well for say, a rock,

because we do not see the properties of a rock as engaged in coordinated kinds of activities contributing to hierarchies and producing homeostasis. We do not ask what the components of a rock are doing for the rock as whole, other than to say that the chemical bonds comprising its matter are of the kind that keep it solidified in some patch of space and time. However, an organism like a dog would seem to require a different kind of description as an entity having components whose emergence is related to the coordination of those components and their homeostatic outcomes in a hierarchically organized system; otherwise, one is in danger of *under*describing a dog's subsystems and processes *just as* a mass made up of chemical properties having certain kinds of bonds, subject to laws of electromagnetism, gravity, etc. There is more to the dog's kidney, for example, than physical laws and chemical bonds. As a biologically emergent entity, the dog's kidney: has a specific function it performs in the dog's digestive subsystem; functions in such a way as to be coordinated with the functioning of other organs in the digestive subsystem; and is related to other organs in the system as a whole in such a way so as to aid in the maintenance of the dog's life.

## Internal–Hierarchical Data Exchange

How it is possible for the operations in this biological hierarchy to be carried out at a certain level, and/or that the operations at lower levels are able to affect and be effected by higher levels, and vice versa? This is accomplished by *internal–hierarchical data exchange*, which refers to the fact that data must freely flow between and among the various levels of the organism. A piece of data is *the raw material that is of the kind that has the potential to be useful for a process or operation.* Datum is exchanged between the components at one level of operation, among the various processes of a subsystem, and among the subsystems that make up the organism as a whole. In this sense, the operations and processes must exhibit a certain amount of malleability and flexibility so that data can actually be exchanged. The data can take the physical form of an electrical charge, an electron, a molecule, or a chemical transmitter. Examples of this kind of data exchange abound in organisms, but we will take a look at one representative example.

A euglena is a one-celled microorganism that is a member of the protist kingdom; in colloquial terms, it is known as a kind of algae. Euglenas are about 10 micrometers in length, and look like a sperm cell with a more elongated body. They are equipped with a flagellum, eyespot, vacuoles, chloroplasts, plastids, and a cell nucleus. Each one of these components has a function: the flagellum is a whip-like tail that enables the euglena to move around; the eyespot is light/dark sensitive so that the euglena can move toward sunlight, its food source; vacuoles allow for wastes to be disposed;

chloroplasts transform sunlight to energy and food; plastids store the food; the cell nucleus contains a nucleolus that synthesizes and encodes ribosomal RNA, which is important for euglena structure and reproduction.

Referring again to our hierarchical model, an organism is an organized system composed of subsystems that are made up of components engaged in processes whose activities produce the particularized and generalized homeostasis of the system. For an organism like the euglena to function effectively in some external environment — basically, live its life in its microbial world — it is necessary that data are exchanged between and among the various subsystems of this system. Food storage in the euglena can be viewed as a subsystem activity, which itself is made up of processes concerning electron transport and oxygen exchange in photosynthesis. In this activity, the data consist of electrons and oxygen molecules. The data must be exchanged between the two processes; otherwise, there would be no storage of food. At the same time, this subsystem works with the subsystems concerning food acquisition and mobility. If data were not being exchanged between the eyespot and the flagellum, then there would be no movement toward sunlight; in turn, there would be no photosynthesis, and then no food storage.

## Data Selectivity

Raw data are exchanged between and among the various subsystems and processes of the organism. However, not every piece of data is relevant or useful to a subsystem or process. There must be some property of the components of an organism that allows for discrimination or parsing between relevant and irrelevant data. Once datum has been selected as useful for a process, it becomes *informative* for the process; the selected datum ceases to be potentially useful, and become actual *information*. Raw data have the potential to become information, and information can be understood as *data of the kind that have been selected for their usefulness for a process or system in an organism*. So, there are actually three categories of data: (a) data that are *not* of the kind that are either useful or not useful for a subsystem or process; (b) data that *are* of the kind that are *not* useful for a subsystem or process; and (c) data that *are* of the kind that *are* useful for a subsystem or process, viz., information.

The term *information* can be defined in different ways, usually depending upon the intended goals of a particular intellectual discipline or methodology employed. Some molecular biologists use the term in the spirit of Shannon's (1948; Weaver and Shannon, 1949) information theory to describe any general communicative process that *selects* one or more objects from a set of objects (Pierce, 1980; Sacco, Copes, Sloyer, and Stark, 1988; Schneider, 1986). However, a few more conditions should be added to this definition in order to make it more appropriate for our discussion.

First, given the molecular biologist's definition, it is correct to say that information entails a selective process. As has been noted already, it is the selective capacity of the components of an organism that enables raw data to be considered as information. Consider that there are a multitude of activities being performed by organelles within the eukaryotic cell. The plasma membrane is the phospholipid bilayer that acts as the cell's shell. In the processes of endocytosis and exocytosis, materials are moved into and out of the cell through the plasma membrane. However, *not just any material* is allowed into or out of the cell. There must be some mechanism of discrimination employed in these processes so that the correct kinds of organic molecules come into the cell as *nutrients*, and the correct kinds of organic molecules get expelled as *wastes*. The data being exchanged in both cases are organic molecules. But the cell processes can discriminate and select which molecules are useful, and which molecules are harmful.

Second, these molecular biologists describe information as a communicative process. This seems correct as information is a kind of medium between, on one hand, something doing the communicating, and on the other hand, something doing the receiving in some environment. In other words, communication of information entails that there be some kind of *afferent* entity and some kind of *efferent* entity, as well as some kind of environment in which this communication can occur. Insofar as this is the case, information can be considered as a *communication on the part of some afferent entity (the communicator) that evokes a change or modification in the efferent entity (the receiver) in an environment, influencing the subsequent activity of the efferent entity.* Using our example of the eukaryotic cell, carbon, nitrogen, and oxygen molecules (the communicator) pass by the plasma membrane (the receiver), and can be understood as informative and incorporated into the body of the cell as energy (the influence). Conversely, organic molecules that are expelled as wastes by cell A (the communicator) can be understood as informative for nearby cell B (the receiver), to the extent that cell B does not try to intake cell A's waste (the influence).

Third, it would seem that some kind of storage or imprinting mechanism would need to exist in the receiver, even if this storage only were to endure for a short amount of time. Such a storage mechanism is necessary so that the information actually can be influential for the efferent entity. For example, when a cell divides in two during cellular mitosis, the offspring cell receives the genetic information from its parent cell. The genetic information from an initial parent cell (or parent cells) is housed in every one of the cells of a multi-cellular organism. This is why it is that biologists can refer to organisms as "genetic information houses" (Dawkins, 1986; Gould, 2002). If that information from the parent cell was not stored somehow in the nucleolus of

the offspring cell, then the offspring cell could not continue to pass on genetic information in its own process of mitosis.

Finally, afferent entities have the potential to become efferent entities, although not in exactly the same respect, and vice versa: cells are generated by mitosis, but then generate their own mitosis; the plasma membrane takes in, but then expels organic molecules; the medulla of the brain receives messages from, and then sends messages to, the heart and lungs; drone bees perceive that food is present through the use of the visual system, and then communicate this information to the rest of the hive by visual means. Organisms operate in such a way that information can be readily communicated and accepted by the same systems, processes, traits, etc. In this sense, there is a certain *malleability* or *flexibility* to be found in the subsystems and processes of organisms.

Having both defined information and described the conditions concerning information exchange, we now can give a few more examples of this kind of activity in organisms.

*Example 1.* Successful gene transfer in reproduction entails that genetic information is passed along from parent organism to offspring organism (Audesirk et al., 2002; Campbell and Reece, 1999; Mayr, 1997). The parent organism acts as the communicator, the offspring as receiver. The genetic code is the information that is communicated from parent to organism. The offspring is affected by this genetic information, since such information determines the offspring's structure and activity. The genetic information is stored in the DNA located in the nucleus of the cell and, in conjunction with environmental factors, continually shapes the structure and activity of the organism throughout its lifespan.

*Example 2.* When a neuron produces an action potential (colloquially, when it *fires*), information associated with spiking signals is communicated between that neuron and at least one other neuron. The axon of one neuron A acts as a communicator and the dendrites of another neuron B, to which the axon of neuron A is connected, acts as a receiver. Protein synthesis in neurotransmitter release is the information that is communicated between neurons (Audesirk et al., 2002; Crick, 1994; Kandel et al., 2000). Depending on the amount and intensity of the neurotransmitter emitted from the communicator neuron, the receiver neuron may become excitatory, making it more likely to produce its own action potential. Networks of neurons can fire more quickly when they are used more frequently, as if the information associated with the particular network's firing has been stored (Felleman and van Essen, 1991; Nicholls, Martin, Wallace, and Fuchs, 1992). The complex inter-workings of trillions of these connections throughout an animal with a nervous system enable it to fight, flee, forage, feast, etc.

*Example 3.* Cells use energy, and one of the primary functions of the mito-chondrion of an animal cell is to produce energy for the cell by converting sugars into a nucleic acid called ATP. However, this can happen only if there is a line of communication between other organelles of the cell and the mito-chondria themselves. ATP acts as the material catalyst of information com-municated between mitochondrion and other organelles. When there are low levels of ATP, the mitochondria receive this information and convert more sugars; conversely, when sugars are converted (this activity, among other activities), the other organelles receive this information and cellular homeostasis can be maintained (Allman, 2000; Audesirk et al., 2002).

*Example 4.* A clear illustration of the communication of information in a systemic fashion is a mammal's muscle coordination in a *reflex arc.* In this activity, information is communicated to and from the spinal cord and a par-ticular muscle group of the body (Crick, 1994; Kandel et al., 2000; Pelligrino, Fadiga, Fogassi, Gallese, and Rizzolatti, 1996). Consider a situation where a very curious cat decides to jump atop a very hot stove. The intense motion of the molecules from the stovetop impress themselves upon the pads of the cat's paws. That motion affects the sensory neurons in the cats skin, causing them to fire. The sensory neurons send a message to the interneurons and, in turn, a message is sent through motor neurons to the spinal cord. These *messages* consist of billions of action potentials and neurotransmitter releases, affect-ing cell after cell that is along the pathway of this particular reflex arc. In an instant, the spinal cord then sends a message back to the muscle groups asso-ciated with the cat's legs, diaphragm and back. In a flash, the cat jumps off the stove, screaming while arching its back.

However, now the cat must coordinate its fall to the ground. This time, information is sent from the visual system to the brain, and then back through the spinal cord to other muscles in the cat's body. All of this infor-mation must be integrated by the brain, and motor responses must be orches-trated by the combined effort of brain–body communication of information. The cat narrowly avoids falling into the garbage can placed next to the stove.

We can now be more precise concerning the kind of activities in which organisms are engaged. This fourth example not only helps to demonstrate how information is communicated in organisms, it also serves to bolster the claim that organisms are *hierarchically organized systems of information exchange.* This is so because information must flow between the subsystems of the organism, as well as within the particularized processes of the subsystems themselves, in order for an organized expression of the organism's activity to take place. Our curious cat utilized — at least — the endocrine, nervous, muscular, respiratory, skeletal, and visual subsystems in its body while jump-ing, screaming, and negotiating space. Similarly, for a euglena there must be a flow of information between eyespot and flagellum in food acquisition, just

as there must be a flow of information between chloroplasts and plastids in food storage. Finally, consider all of the information being exchanged between and among the organelles of an animal cell. The nucleus is in constant communication with each mitochondrion, peroxisome, lysosome, centriole, Golgi apparatus, ribosome and endoplasmic reticulum, each of which has its own function in maintaining the overall homeostasis of the cell.

## Informational Integration

The mere fact *that* information is exchanged among the various processes and subsystems of an organism does not seem to capture fully or adequately the nature of an organism as a hierarchically organized system. The distinction between higher and lower levels in a hierarchy suggests that the higher levels exhibit significant *control* over the lower levels (see Cziko, 1995). There seem to be heuristic mechanisms that emerge from the complex operations of processes and subsystems. This makes sense since the more complex some process or system becomes, the more there is a need for mechanisms of control so that the process or system can operate efficiently. These mechanisms are like *command centers* where activity can be integrated and monitored, much like the central processing unit (CPU) of a computer. In fact, Sperber (1994), Dennett (1991), Johnson–Laird (1988), and Dawkins (1986), each in their own way, envision computational systems equipped with CPUs as appropriate models of biological processes.

Now, there are at least two modes of control present in an organism conceived of as a hierarchically organized system, viz., *selectivity* and *integration*. Selectivity is a mode of control since this property of organisms acts as a kind of filtering mechanism distinguishing raw data from information. Biologists and evolutionary theorists use the word *constraint* to describe mechanisms of selectivity associated with organisms, whether they are talking about cellular processes (Rosen, 1968), embryological development (Amundson, 1994), visual attentiveness (Hatfield, 1999), the *fight or flee* response (Nesse and Abelson, 1995), organismic homeostasis (Audesirk et al., 2002), or the adaptability of organisms to environments (Darwin, 1859/1999; Gould, 1980).

In the four examples from the previous section, we can describe forms of selectivity that manifest a mode of control. In example 1, genetic information is passed along from parent to offspring, but the gene transfer in reproduction is *restricted* to a particular species. Genetic information cannot pass from euglena to cat, or from human to euglena, for example (Hastings, 1998; Kitcher, 1992; Mayr, 1976). With respect to example 2, proteins actually contribute in *regulating* the amount of neurotransmitters that can be released into a given synaptic cleft when a neuron fires (Allman, 2000; Audesirk et al., 2002; Kandel et al., 2000; Nicholls, Martin, Wallace, and Fuchs, 1992).

In example 3, mitochondria are said to *filter* any excess glucose to facilitate cellular homeostasis (Allman, 2000; Audesirk et al., 2002). Finally, in example 4 the brain ultimately can *control* the amount of force exerted in a jump (Audesirk et al., 2002; Cziko, 1992, 1995; Kandel et al., 2000; Pelligrino, Fadiga, Fogassi, Gallese, and Rizzolatti, 1996).

Once useful data have been selected for — thereby becoming information — they still need to be integrated into the overall workings of a process or subsystem. *Informational integration* is another mode of control in the organism viewed as a hierarchically organized system, and refers to the fact that *the various processes and subsystems in an organism are equipped with a capacity to organize the information that has been selected for by the processes and subsystems so that, ultimately, generalized homeostasis can be achieved.* Processes and subsystems achieve particularized homeostasis, the results of which contribute to generalized homeostasis in an organism. If there was not some mechanism by which the pieces of information were organized in processes and subsystems, then the hierarchy would not achieve generalized homeostasis, thereby ceasing to function or, at least, ceasing to function optimally in some environment. Selectivity and integration are like two sides of the same coin concerning control in an organism conceived of as a hierarchical organization — both are needed for proper functioning of the components and, consequently, for particularized and generalized homeostasis of the organism.

Consider an analogous thought experiment: if a painter selects all of the colors for a painting, but then splashes the colors on the canvass in a random fashion, there would be no organized piece of art produced (unless the goal is some modern art piece *intended* to be randomized). Or, consider that the very idea of a *system* entails a coordination of the components that make up the referent of such an idea. What would happen to a system if there were no integration of information to be found therein, i.e., no coordination of components in the processes and subsystems that make up such a thing? The system would cease to be known as, and cease *to be*, a system, really. Instead it would be known as, as well as become, an *aggregate* of some sort.

Informational integration is achieved at many levels in an organism, from the coordinated functions of organelles in a cell, to the coordinated cellular processes in an organ, to the coordinated activities of organs in a subsystem, to the overall coordination of the subsystems of the organism. Further, in a multi-cellular organism like an animal, all of these processes and subsystems function together in coordinated ways to produce the generalized homeostasis of the organism. The image of a triangle that was used in Figure 2 is all the more appropriate as a schematization of an organismic hierarchy, in light of this property of organisms. The subsystems near the top part of the triangle control the entire system, just as the processes near the top of a subsystem control the subsystem, through the integration of information received from

lower levels. Analogously, we can think of organizations like the Catholic Church or a corporation as manifesting this triangular model in their own actions and interactions. The Pope and other Bishops are at the top of the Church triangle, and exhibit control over the rest of the Church as a whole. So too, the corporate members — CEO, CFO, etc. — are at the top of the corporation triangle, and exhibit control over the corporation as a whole.

### The Neurobiological Basis of Selectivity and Integration: The Hierarchical Organization of the Mammalian Visual System

There is an elegant consistency in the hierarchical organization exhibited from the micro-level of the neuron to the macro-level of the vertebrate nervous system. This consistency is echoed in Bear, Connors, and Paridiso's (2001) claim that the "signaling network within a single neuron resembles in some ways the neural networks of the brain itself" (p. 161). Hierarchies exist within hierarchies, and the visual system is one of those hierarchies that functions so as to aid in producing the architectonic organization of the nervous system of an animal (cf. Allman, 1977, 1982; Casagrande and Kaas, 1994; Crick and Koch, 1990; Desimone and Ungerleider, 1989; Kosslyn and Koenig, 1995; van Essen and Gallant, 1994).

These hierarchies are able to interact with one another because of *internal–hierarchical data exchange* whereby data — the raw material that are of the kind that have the potential to become useful for a process or operation — are exchanged between and among the processes and subsystems at various levels of operation in an organism. In their textbook devoted to the principles of neuroscience, Kandel et al. (2000) describe the processes associated with perception in the cerebral cortex using a hierarchical model:

> Sensory information is first received and interpreted by the primary sensory areas, then sent to unimodal association areas, and finally to the multimodal sensory areas. At each successive stage of this stream more complex analysis is achieved, culminating eventually, as with vision, for example, in object and pattern recognition in the inferotemporal cortex. (p. 353)

Kandel et al. actually divide the hierarchy of sensory systems into four parts: (a) the primary sensory areas; (b) the unimodal areas; (c) the unimodal association areas; and (d) the multimodal association areas.

The primary sensory areas act as the base level, and they refer to the way in which information initially is communicated to the spinal cord and/or brain through one of the five sensory modalities, viz., touch, hearing, taste, smell, and vision. For example, in the visual system the primary sensory area is comprised of the eye, lateral geniculate nucleus, and the primary visual cortex located in the occipital lobe of the brain. The unimodal areas build

upon the data received from some prior particular primary sensory area, and refer to a higher-leveled integration of the data received from one of the primary sensory areas processed in a part of the brain different from that of the primary sensory area. In the visual system, there are two primary unimodal areas that process information concerning *where* an object is and *what* an object is, located along trajectories between the occipital lobe and parietal and temporal regions, respectively. The unimodal association areas, in turn, refer to an even higher-leveled integration of the data received from two or more unimodal areas. In the visual system, the unimodal association area integrates data about the color, motion, and form of objects, and is located in the occipitotemporal area of the brain. Finally, the multimodal association areas build upon the data received from the unimodal association areas, and depending upon the sensory modality, process this information in either the parietotemporal, parietal, temporal, and/or frontal areas of the brain.

## Data Selectivity in the Visual System

Visual perceptions are integral to our conscious experience of ourselves and the world around us. This is one reason Crick and Koch (1998) give as to why they study the visual system in trying to understand consciousness and its neural correlates: "Humans are very visual animals and our visual percepts are especially vivid and rich in information" (p. 98). This is also why Logothetis (1999) titles his article in *Scientific American*, "Vision: A Window on Consciousness" (p. 69). Finally, this is why, after a lengthy discussion regarding the relationship between the visual system and consciousness, Damasio (2003) has claimed that "without mental images, the organism (viz., a human) would not be able to perform in timely fashion the large-scale integration of information critical for survival, not to mention well-being" (p. 208).

Now, the complex processing of information in the nervous system seems to require the fourfold steps of (1) detecting data in some environment, (2) *discriminating between relevant and irrelevant data,* (3) integrating information, and (4) initiating some kind of response, as Audesirk et al. (2002), Kandel et al. (2000), and Sekuler and Blake (2002) each have noted in their own ways. The goal of this section is to focus upon the second step of this process. It will be demonstrated that there is data selectivity occurring at virtually every level of visual processing, from the activities of photoreceptors in the retina, to the columnar and blob-cell firings, all the way up through the *what* and *where* unimodal systems, to the unimodal and multimodal association processes occurring in the occipitotemporal, parietotemporal, prefrontal, and limbic cortices. This data selectivity makes it possible for the components of the visual system to process data and make use of these data as information.

Visual processing is already occurring in the retina, and this entails that the various kinds of neurons therein actively are selecting data that are relevant to their specific function. The retina is specialized to detect differences in the intensity of light falling upon it, since the rods selectively attend to dim light, while the cones selectively attend to intense light. Sekuler and Blake (2002) underscore this selective capacity in the retina by noting that "events in the retina shape vision by emphasizing some information and by de-emphasizing other information" (p. 91). Continuing, they claim:

> This information from the retina then is sent through the ganglion cells to the brain. Data selectivity continues in the occipital lobe where orientation-specific and ocular-dominance columns respond to lines and depth respectively, while the blobs process color. The specification of functions in the M and P cell pathways further attests to this data selective property of the visual system, since the M cells respond to depth, motion and object position, while the P cells respond to form and color (p. 91; cf. Goodale et al., 1994; van Essen and Gallant, 1994).

The most complex level of the visual system makes connections in the multimodal association areas of the prefrontal, parietotemporal, and limbic cortices. Research shows that the prefrontal areas primarily are responsible for motor planning, judgment, some memory, and language production, while the limbic cortices are responsible for olfaction, emotion, and some memory formation as well. Research also shows that the parietotemporal lobe aids in sensory integration of visual space and language, but most importantly, *spatial attention* (Lux, Marshall, Ritzl, Zilles, and Fink, 2003; Milner and Goodale, 1995; Wurtz, Goldberg, and Robinson, 1982). Further, Brefczynski and DeYoe (1999), Desimone and Duncan (1995), Julesz (1984), and Treisman (1977, 1988) have proposed a mechanism associated with attention whereby the brain selectively associates the disparate features of the visual scene for a short time. The associated data are considered as *spotlighted*, and comprise the coherent visual scene of which an animal is aware (cf. Poggio and Hurlbert, 1994; Posner and Dahaene, 1994; Posner and Petersen, 1990).

The intention here is simply to point out the importance of a mechanism of selection or segregation that seems to be present in the visual system at all levels of the hierarchy. Animals are bombarded with sensory data in droves. There would be no way for the sensory systems of the animal to take in all of these data; if they did, the animal probably would cease to function altogether, much like an overloaded computer that shuts down (see Johnson–Laird, 1988; Moravec, 1999a, 1999b). Thus, there are selectivity mechanisms — kinds of *selectivity* or *filtering devices* — that exist all along the processes in the visual hierarchy, segregating relevant from irrelevant data. The relevant data become processed as information, while the irrelevant data are simply ignored. The visual system exhibits its own checkpoints of selectivity, from

the interactions among organelles in the neuron, to the retina's ability to detect differences in the intensity of light, to the spotlighting of visual information at the higher levels of the visual hierarchy. This is why, while researching the visual system, van Essen, Anderson, and Olshausen (1994) call our attention to mechanisms "for dynamically *regulating* (italics mine) the flow of information within and between cortical areas" (p. 271). Also, as Zigmond, Bloom, Landis, Roberts, Squire, and Wooley (1999) note, in the visual system "high-level neurons classify visual stimuli by integrating information that is present in the earlier stages of processing, but also by ignoring information that is independent of that classification" (p. 822).

## Informational Integration in the Visual System

It was noted that the complex processing of information in the nervous system seems to require the fourfold steps of (1) detecting data in some environment, (2) discriminating between relevant and irrelevant data, (3) integrating information, and (4) initiating some kind of response. The third step in this process will be the focus of this section, as it will be shown that integration is a key feature of the visual system, especially when considering the relationship the animal has to its external environment. True, the visual system detects and then selects or segregates information; however, since selection alone cannot account for how this information is organized for some purpose, neural networks possess an ability to integrate the information so as to aid the animal in optimally negotiating some environment. Once the information has been selected, it must be organized in a coherent manner so that an animal can go about the business of feeding, fighting, fleeing, reproducing and the like, in the most optimal and efficient manner possible.

Such integration is made evident, for example, in the visual system's ability, through the visual unimodal association area, to align shape and color in the *what* system with distance and position in the *where* system so as to visually process an approaching predator (Crick and Koch, 1990; Goodale, Meenan, Bulthoff, Nicolle, Murphy, and Racicot, 1994; Goodale and Murphy, 2000). Another example of this integration is the ability of the higher areas of the visual system to extract a coherent three-dimensional picture of a visual scene from two-dimensional images on the retina. Other examples include the integration of information specifying relations of depth among objects, as well as the integration of information specifying the distance between a perceiver and an object (Bruno and Cutting, 1988).

It would seem that any organized hierarchical system — including the visual system — must come together part-by-part, with the separate parts, at first, functioning so as to solve a certain distinct problem. This is how computer networks are built up from the fundamental *ifs* and *thens* or the *1*s and *0*s, to the

more complexly functioning Big Blues or world-wide-webs (Johnson–Laird, 1988; Moravec, 1999a; Sperber, 1994). This is also the way natural/historical processes appear to work in evolutionary advances (see Berra, 1990; Cosmides and Tooby, 1992; Dawkins, 1996; Deacon, 1997; Gould, 1977). So it is understood by neurologists, philosophers, psychologists, and other thinkers that the mammalian visual system is made up of parts or *brain-process modules* that have been selected for in an evolutionary history to process color, shape, depth, motion, the edges of objects, and the like (Crick and Koch, 1998; Edelman and Tononi, 2000; Goodale and Murphy, 2000; Kosslyn and Koenig, 1995; Marr, 1983; Shallice, 1997). At the same time, such an organized hierarchical system seems to have evolved heuristic mechanisms that can both segregate or select certain parts as relevant, *as well as* integrate or bind relevant parts together, so as to adapt to an environment. Thus, van Essen, Anderson, and Olshausen (1994) maintain that the "need for highly flexible linkages between a large number of physically separate modules" (p. 271) requires a mechanism that *controls* and *integrates* the information gathered from such modules.

It is important for an animal's survival that it be able to select relevant visual information about color, shape, distance, etc. from the environment, and then integrate that information so as to know whether to fight, flee, eat, mate, etc. In other words, the recognition and discrimination of objects is key to an animal's survival. A question now arises: How is it that the disparate pieces of selected data — which have been carried by separate pathways at the various levels of the visual hierarchy — are organized into a coherent visual perception, enabling object recognition and/or discrimination? This is actually a kind of *binding problem* question, of which there are probably many at the various neurobiological and psychological levels of the visual system (Gray, 1999; Roskies, 1999). Another way to frame the question is: How is it that the parallel processing of lines, shapes, forms, colors, motion, distance, depth, and the like are combined in such a way as to yield the image of a particular object in your visual field, and not of something else entirely? How is this information coherently integrated or *bound together* so as to become informative for the perceiver?

It will be suggested here that this is possible through the phenomenon of *visual modularity* and the mechanism of *visual integration*. When relevant visual areas are bound together so as to make coherent sense out of some external stimuli in terms of object-recognition or discrimination, this *bundle* comprises the integration of visual modules.

Visual modularity refers to *the fact that the visual system is made up of distinctly functioning and interacting modules, parts or areas, having evolved to respond to certain features of an object in typical environments.* A module, in this sense, is simply *a brain process or brain system devoted to some specified task concerning object recognition and/or discrimination.* The concept of the module is nothing

new, and has been utilized by neuroscientists, biologists, evolutionary psychologists, and other thinkers for years (see Bruno and Cutting, 1988; Cosmides and Tooby, 1992; Gardner, 1993; Kosslyn and Koenig, 1995; Marr, 1983; Mithen, 1996; van Essen et al., 1994).

For example, the visual cortex and related pathways are split up into many areas, each processing a different aspect of the visual field: V1 is responsible for initial visual processing; V2 for stereo vision; V3 for distance; V4 for color; V5 for motion; and V6 for object position. Each of these processes can be viewed as a module, as Marr (1983) makes clear in his famous work on vision. DeYoe, Felleman, van Essen, and McClendon (1994) have shown that the blobs and interblobs of V1 and V2 in macaque monkeys contain neurons with distinctive visual response properties suggesting modularity and multistream processing. Also, Broca's area and Wernicke's area would be considered as other examples of brain-process modules, since grammar-usage and language comprehension appear to be localized in these areas, respectively (see Lueders, Lesser, Hahn, Dinner, Morris, Wyllie, and Godoy, 1991; Patterson and Wilson, 1987). Further, the face-recognition area in IT cortex already mentioned is another example of a brain-process module (Tovee and Cohen–Tovee, 1993; Tovee, 1998).

The phenomenon of visual modularity works with the mechanism of visual integration to produce a coherent visual perception. Visual integration refers to *a neurobiological process or set of processes that bind together the relevant information gleaned from visual modules into a coherent, cognitive representation of some object, enabling an organism to function in typical environments.* As Zigmond et al. (1999) note, in the visual system "high-level neurons classify visual stimuli by integrating information that is present in the earlier stages of processing" (p. 822).

Consider a possible exchange between two monkeys: monkey A has food and monkey B wants monkey A's food. If monkey A is being approached by monkey B, it must be able to visually judge space and shape (*What* is this thing coming at me?), along with distance and size (*Where* is this thing in relation to me?), as well as interpret the facial expressions of its approacher. The *what* and *where* systems follow trajectories from the visual cortex to the temporal/ventral and parietal/dorsal areas, respectively, and facial recognition has neural correlates found in the IT cortex. All of this modular processing occurs in a parallel fashion, by separate modular processes, as neuroscientists indicate (e.g., Crick, 1994; Desimone et al., 1984; Felleman and van Essen, 1991).

When facial recognition, body position, and proximity are brought to cognition, as when monkey A communicates to monkey B something like *this is my food, don't touch it or I'll bite you*, there must be an integration of this modular information so that the monkey can form a coherent perception.

Further, there are various sorts of stimuli coming in through the other sensory modalities that need to be integrated with the visual system so that monkey A ultimately can initiate a response in terms of either fighting, fleeing, making friends, or some other response. The brains of our monkeys bind together the various modules of the visual system, as well as bind together the visual system with other systems, while negotiating this exchange. The phenomenon of visual modularity and the mechanism of visual integration work together to explain how this exchange between these two monkeys is possible.

## Conscious Selection and Integration

Now think of a possible exchange between two humans. In the same way that visual integration performs the function of segregating and integrating visual module areas, so too, consciousness emerged as a property of the brain to act as a kind of *metacognitive* process that not only is the intermixing and interplaying of psychological modules, but actively selects and integrates information from psychological modules, in performing certain functions (such as the solving of problems) in environments. Put another way, just as the visual system working in tandem with other parts of the brain actively fills in the needed space so as to attain a coherent picture of the octagon utilized in Figure 1, so too, consciousness actively selects and integrates information so as to attain a coherent "picture" utilizing psychological modules. Again, in the Kantian spirit, the mind is an active thing, and consciousness represents the most complex emergent activity of the mental hierarchy.

Figure 3 is a schematization that has to do with the generating of a piece of artwork by one of our early hominin ancestors. This schematization is supposed to represent the slower, intelligent processes associated with consciously selecting and integrating visual information between and among mental modules so as to imagine a novel piece of art. Like problem solving, toolmaking, and generating meta-theories, producing a novel piece of art entails a conscious ability to actively select and integrate information from mental modules so as to produce a mental product. The figure concerns the construction of fish–human figurines discovered by archeologists at the site of Lepenski Vir on the Danube, and dated to about 7,000 years ago (Mithen, 1996). These are considered pieces of artwork, probably constructed for some religious significance. These figurines are significant because they are some of the first pieces of art constructed by hominins whereby it could be said that the artist did not already possess an image of *that particular kind of finished product* in his/her mind. There have been fish figurines and human figurines found that pre-date these figurines, but never specifically *fish–human* figurines.

Although the exact kind and number of mental modules is in dispute among evolutionary psychologists, developmental psychologists, neuroscientists,

philosophers, and other thinkers, there seems to be a general agreement that
there is something to the evolutionary psychologist's position that the mind
is made up of mental modules that have evolved to solve specific problems
encountered in environments, whatever those environments may be (see
Arp, 2005; Buss, 1999; Cosmides and Tooby, 1992; Daly and Wilson, 1999;
Kanazawa, 2004; Mithen, 1996; Pinker, 2002; Scher and Rauscher, 2003;
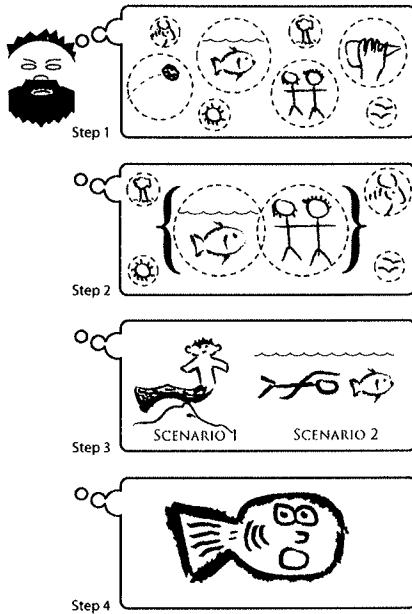Shettleworth, 2000).



Figure 3: The construction of a fish–human figurine.

In the first step, in line with the evolutionary psychologist's suggestion that
the mind contains a suite of mental modules, the artist has separate visual
images of human and animal morphology and behavior, along with other
modules concerning physical, biological, and sociological matters. The infor-
mation between the two spheres has the potential to intermix, and is repre-
sented by the dotted-line bubbles. In the second step, selectivity is beginning
as the human and animal modules are bracketed off or segregated from the
other modules. In the third step, this conscious activity is continuing as the
artist is transforming, adjusting, and re-configuring the information regarding
fish and human characteristics in some imagined future visual scenario. In
the fourth step, the information regarding fish and humans has been inte-

grated, and a wholly new image — the fish–human — has been formed. Again, the idea being schematized here is twofold: (1) the finished product in the artist's mind (the fish–human figurine) is the result of the conscious selection and integration of mental modules; (2) the conscious psychological properties of selectivity and integration are possible because of similar properties that other neurobiological and biological processes exhibit.

What areas of the brain would be likely candidates for visual integration, enabling this conscious activity, ultimately, to occur? We know that the *what* and *where* visual unimodal systems are laid out along trajectories from V1 in the occipital lobe to the temporal and parietal regions, respectively. And we know that different aspects of an object — color, form, distance, and the like — are processed along each one of these trajectories. There appears to be some kind of integrating mechanism that allows for the primate to determine either what an object is or where an object is that is present in each of these systems. Information about an object from V1, V2, and V4 must be integrated somehow along the trajectory that forms the *what* system; likewise, information about an object from V1, V2, V3, V5, and V6 must be integrated somehow along the trajectory that forms the *where* system. We can infer that integration of information is taking place from the fact that if the *what* system is non-functioning, a primate still may be able to distinguish where an object is; conversely, if the *where* system is non-functioning, a primate still may be able to distinguish what an object is (Desimone and Ungerleider, 1989; Goodale and Murphy, 2000; Ungerleider and Haxby, 1994; Ungerleider and Mishkin, 1982). How would a primate be able to coherently determine the what or the where of an object *independent of one another* if the information from these areas was not somehow integrated along the individual trajectories?

Further, the very concept of an *association area* implies an integrating mechanism. Thus, it is likely that the visual unimodal association area of the occipitotemporal cortex acts as the integrative mechanism for the information processed from the *what* and *where* visual unimodal systems. This area is involved in processing the information received from the parietal and temporal unimodal areas concerning color, motion, depth, form, distance, and the like. We know that there is a division of labor concerning a primate's abilities to distinguish what an object is from where an object is. However, there are times when a primate must perform both of these tasks, and given the neuronal projections from the parietal and temporal areas to this common site in the occipitotemporal cortex, it makes sense that a primate be able to integrate visual information about what and where an object is in its visual field at the same time. Kandel et al. (2000) claim that these areas integrate information about form, color and motion, noting that their evidence comes directly from studies of humans who have suffered brain injuries, experimental studies on monkeys and radiological imaging techniques of humans (pp. 350–351).

Beason–Held et al. (1998) have shown through PET scans that the occipito-temporal lobes are active in elementary form perception in humans. Also, Honda, Wise, Weeks, Deibel, and Hallett (1998) noted the activation of these areas in PET scans when humans performed visuomotor tasks in a matching-to-sample test where both the *what* and *where* systems were utilized.

Also, it may be plausible to posit that the multimodal areas act as the neuronal integrating mechanism for the information that is processed through the highest level of sensory systems and those systems associated with memory, attention, planning, judging, emotions, and motor control. Kandel et al. (2000) name the prefrontal, parietotemporal, and limbic cortices as the most likely neural candidates. Rees and Lavine (2001), Roberts, Robbins, and Weiskrantz (1998), and Uylings and van Eden (1990) point to these areas as primary integrating mechanisms for higher-level functions, including conscious awareness. Through PET scans, Macaluso, Frith, and Driver (2000) have shown that the unimodal and multimodal areas are active in tasks involving the utilization of both the visual and somatosensory systems (also see Calvert, 2001; Eimer and van Velzen, 2002).

## A Concluding Note: Psychological Emergence

Words like *cognition, awareness,* and *perception* all refer to similar psychological discriminatory abilities of an animal. Earlier, we spoke about emergentism, and it was argued that the components of an organism are emergent entities non-reducible to the physico-chemical parts of which they are composed based upon the way in which the components are organized to do something directly related to the generalized homeostasis of this hierarchically organized living system. The psychological dimension associated with the brain's activities can be considered as another level of emergent phenomena added to the hierarchy. This is so because cognition appears to be organized in such a way as to aid an animal in discriminating information in environments so as to fight, flee, feast, forage, etc. However, the kind of end result or end product of cognition — although similar to other activities in the animal's hierarchy in having generalized homeostasis as the goal — is different in that such a product is a *psychological* phenomenon that aids in generalized homeostasis.

There is a huge amount of literature devoted to questions about the existence of psychological phenomena, and whether psychological phenomena supervene upon or emerge from neurobiological phenomena (see Chalmers, 1996; Hasker, 1999; Hatfield, 1999; Kim, 1999, 2000; Lycan, 1995; McGinn, 1982; Mesalum, 1998; Roth, 2000; Searle, 1992). It is arguable that just as the components at various levels of neurobiological and biological hierarchies — such as organelles, cells, tissues and organs — cannot be reduced to the physico-

chemical parts of which they are composed, so too cognition, although dependent upon neurobiological processes, is not reducible to such processes. Again, the main reason why psychological phenomena are non-reducible to neurobiological phenomena is the same reason why neurobiological and biological components are non-reducible to the physcio-chemical parts of which they are composed, viz., such components and phenomena emerge as a result of the way in which they are organized to do something directly related to generalized homeostasis of the organism.

So, we must not think that consciousness is some kind of entity existing *completely* on its own, like some thing totally detached from the processes and functions of the brain. The view being put forward envisions consciousness as an emergent metacognitive *process*, one that utilizes several areas of the brain concerned with the visual system, memory, planning, and voluntary movements. To think that consciousness is some kind of entity completely divorced from the processes of the brain catapults one into what is known as *the problem of the homunculus*, viz., the idea that consciousness is a "little person inside the head" who perceives the world through the senses, as well as thinks, plans and executes voluntary motions (Dennett, 1991).

Unfortunately, if one holds the homunculus view, a few problems result. First, there is the problem of consciousness as being a thing that is too disassociated from the workings of the brain. If consciousness is a thing too disassociated from the brain, then we run into the further problems of: (1) explaining how it is that consciousness, which presumably would exist on a non-biological level, can interact with a brain that exists on the biological level (McGinn, 1982); (2) specifying what the objective laws associated with consciousness would be if they are not biological, physical, chemical, or otherwise scientific laws (Kim, 2000; McGinn, 1982); (3) *third man* kinds of arguments whereby our mental life is (not really) explained by consciousness, which is explained by consciousness$_2$, which is explained by consciousness$_3$, etc., ad infinitum; (4) making consciousness out to be a "spooky" thing (Churchland, 1997) too removed from empirical, objectifiable, third-person evidence.

The account of consciousness as dependent upon biological processes put forward in this paper skirts the problems just listed. All of these problems are avoided because consciousness is *an emergent phenomenon subject to the same laws as any other neurobiological and biological phenomena*. Sperry (1980) has stated the position eloquently: "Consciousness is a functional property of brain processing, constituted of neuronal and physicochemical activity, and embodied in, and inseparable from, the active brain" (p. 204). The psychological realm is an extension of the neurobiological and biological realms. Just as cellular processes exhibit internal–hierarchical data exchange, data selectivity, and informational integration, so too, neurobiological and psychological processes exhibit the same kinds of properties, making for a psycho-neuro-biological continuum.

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