

LIFE AND THE HOMEOSTATIC ORGANIZATION VIEW OF BIOLOGICAL PHENOMENA

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ABSTRACT: In this paper, I argue that starting with the organelles that constitute a cell – and continuing up the hierarchy of components in processes and subsystems of an organism – there are clear instances of emergent biological phenomena that can be considered “living” entities. These components and their attending processes are living emergent phenomena because of the way in which the components are organized to maintain homeostasis of the organism at the various levels in the hierarchy. I call this view the *homeostatic organization view* (HOV) of biological phenomena and, as is shown, it comports well with the standard philosophical accounts of nomological (metaphysical) emergence and representational (epistemological) emergence. To proffer HOV, I describe properties of biological entities that include internal-hierarchical data exchange, data selectivity, informational integration, and environmental-organismic information exchange. Further, a distinction is drawn between particularized homeostasis and generalized homeostasis, and I argue that because the various processes and subsystems of an organism are functioning properly in their internal environments (particularized homeostasis), the organism is able to exist as a hierarchically-organized entity in some environment external to it (generalized homeostasis). Stated simply: that components of biological phenomena are organized to perform some function resulting in homeostasis marks them out to be living emergent entities distinguishable, in description and in reality, from the very physico-chemical processes of which they are composed.

KEYWORDS: Data Selectivity, Hierarchical Organization, Homeostasis, Homeostatic Organization View, Information, Informational Integration, Integration, Selectivity

1. ORGANISMS, HIERARCHICAL ORGANIZATION, AND HOMEOSTASIS

Ultimately, it will be argued that the components and attending processes of an organism must be considered as living, emergent phenomena because of the way in which the components are organized to maintain homeostasis of the organism at the various levels in the organismic hierarchy. Before this is accomplished, however, it is necessary to show that the processes in which the components of this hierarchy are engaged produce homeostasis through abilities to internally exchange data, selectively convert data to information, integrate that information, and process information from environments.

In general, biologists and other researchers who describe biological phenomena are aligned with Mayr (1996) in his description of organisms as “hierarchically organized

systems, operating on the basis of historically acquired programs of information” (Gould, 2002; Audesirk, Audesirk, and Beyers, 2002; Eldredge, 1995; Bogdan, 1994; Lycan, 1995; Csányi, 1996; Collier and Hooker, 1999; Arp, 2008a, 2005b; Arp and Ayala, 2008; Arp and Rosenberg, 2008; Terzis and Arp, 2008). What exactly is entailed in this description? An organism can be defined as: *a hierarchically organized system made up of components that are engaged in processes constituting coordinated subsystems, with the product of these processes and subsystems being homeostasis relative to their operations, producing the overall homeostasis of the system.*

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. The reader may be aware of the fact that, in philosophy of science and philosophy of mind literature, it is now commonplace to find references to Craver’s (2001) description of a mechanism hierarchy as some mechanism S, which is Ψ -ing, composed of smaller entity Xs, which are Φ -ing. These Xs are little mechanisms themselves consisting of smaller entity Ps, which are σ -ing. This view has the benefit of describing some mechanism as a hierarchically organized system, in a non-spooky fashion, consisting of entities engaging in inter and intra-leveled causally-efficacious activities. Craver’s view of a hierarchical mechanism maps onto my schematization of a hierarchically-organized system, and our two views have much in common. However, as I will show in the final section of this paper, his view is lacking certain conditions that enable one to distinguish living systems from non-living ones.

Now, to understand what it means for an organism to be a *hierarchically organized system*, we need to investigate the properties of the components of this kind of system. These properties include what I call the following:

- A. Internal-Hierarchical Data Exchange
- B. Data Selectivity
- C. Informational Integration
- D. Environmental-Organismic Information Exchange

While describing each of these properties, the interactions of the components of this kind of system, as well as the overall coordination of these components will become evident (also see Arp, 2005b, 2008a). 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 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. There are environments exerting pressures upon the subsystems and processes internal to an organism, as well as environments exerting pressures upon the organism as a whole that are external to it. 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.

A distinction can be drawn 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 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 organism is maintained because homeostasis is maintained at the levels of the subsystems and processes comprising the organism.

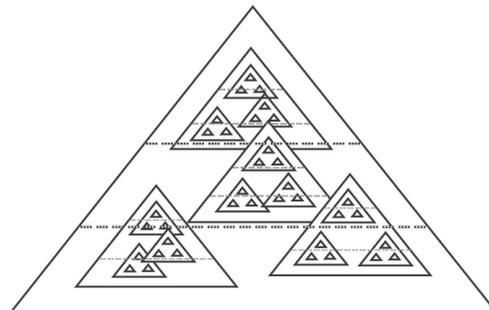
If the various processes and subsystems of an organism are functioning properly in their internal environments – thereby producing particularized homeostasis – the organism is able to function effectively in some environment external to it. This proper functioning that yields internal homeostasis takes 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 the previous 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), it could be said that higher-level subsystems are the phenomena that literally *emerge* from lower-level subsystems and processes (also see the relevant papers in Arp and Ayala, 2008; Arp and Rosenbeg, 2008; Terzis and Arp, 2008). More will be said about emergence in the final section of this paper.

The organism can be conceptualized as a hierarchical organization whereby levels of operation, in the forms of subsystems and processes, function interdependently with one another in this unified system. A schematization of this hierarchical system is shown in diagram 1.

Diagram 1: A hierarchically organized system



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; and 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. (Again, we can recall Craver's description of a mechanism hierarchy as some mechanism

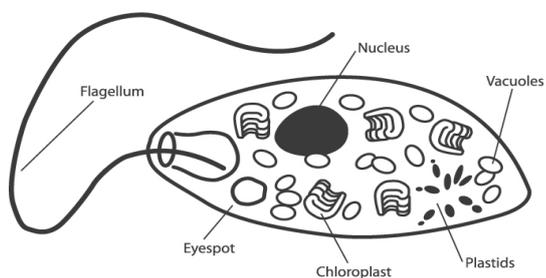
S, which is Ψ -ing, composed of smaller entity Xs, which are Φ -ing. These Xs are little mechanisms themselves consisting of smaller entity Ps, which are σ -ing.)

2. INTERNAL-HIERARCHICAL DATA EXCHANGE

The question now arises as to how it is possible for the operations in this biological hierarchy to be carried out at a certain level, and also how the operations at lower levels are able to affect and be effected by higher levels, and vice versa. This is accomplished by what I call *internal-hierarchical data exchange*. This refers to the fact that data must freely flow between and among the various levels of the organism. Data are *the raw materials that are of the kind that have the potential to be useful for a process or operation*. Data are 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. 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 (see diagram 2). 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.

Diagram 2: *A euglena*



Referring again to the aforementioned 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 existence in its little microbial world – it is necessary that data be 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.

3. 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 a piece of data has been selected as useful for a process, it becomes *informative* for the process; the selected datum ceases to be potentially useful and becomes 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 is either useful or not useful for a subsystem or process; (b) data that *are* of the kind that is *not* useful for a subsystem or process; and (c) data that *are* of the kind that *is* useful for a subsystem or process, viz., information (see Terzis and Arp, 2008).

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 (1948) and Weaver and Shannon's (1949) Information Theory to describe any general communicative process that *selects* one or more objects from a set of objects (Terzis and Arp, 2008; Sacco, Copes, Sloyer, and Stark, 1988; Schneider, 1986; Pierce, 1980). 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. This “discrimination” process is not some “spooky” vitalist phenomenon, and more will be said about this process in later sections of this paper.

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).

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; Mayr, 1997; Voet, Voet, and Pratt, 2002; Campbell and Reece, 1999; Williams, 1992). 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.

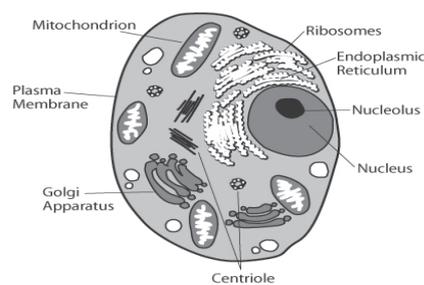
Example 2. Cells use energy, and one of the primary functions of the mitochondrion of an animal cell is to produce energy for the cell by converting sugars into a nucleic acid called ATP. However, this can happen only if there is a line of communication between other organelles of the cell and the mitochondria themselves. ATP acts as the material catalyst of information communicated 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 (Audesirk et al., 2002; Allman, 2000; Voet et al., 2002; Campbell and

Reece, 1999).

Example 3. 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 particular muscle group of the body (Kandel et al., 2000; Audesirk et al., 2002; Pelligrino, Fadiga, Fogassi, Galleste, and Rizzolatti, 1992). 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 cat's 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, affecting 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 associated 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 information must be integrated by the brain, and motor responses must be orchestrated 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 jumping, 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.

Diagram 3: The major organelles of the animal cell



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, centriole, Golgi apparatus, ribosome, and endoplasmic reticulum, each of which has its own function in maintaining the overall homeostasis of the cell (see diagram 3): the nucleus contains the nucleolus and houses DNA; the mitochondrion supplies the cell with energy; centrioles are important for cell division; the Golgi apparatus stores proteins; ribosomes are the sites for protein synthesis; the endoplasmic reticulum expedites the transport of cellular material; the plasma membrane permits materials to move into and out of the cell.

4. 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. 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 CPU of a computer. In fact, Sperber (1994), Dennett (1991), Johnson-Laird (1988), Cziko (1995), and Dawkins (1986), each in their own way, envision computational systems equipped with CPUs as appropriate models of biological processes (also see Arp, 2005a, 2006a, 2007a, 2008a, 2008b).

Now, there are at least two modes of control present in an organism conceived of as a hierarchically organized system, viz., *selectivity* and *integration*. Already, we have seen that selectivity is a mode of control since this property of an organism acts as a kind of filtering mechanism that distinguishes 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 (Gould, 1980; Darwin, 1859).

In the three 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 (Mayr, 1976; Hastings, 1998; Kitcher, 1992). With respect to Example 2, mitochondria are said to *filter* any excess glucose to facilitate cellular homeostasis (Audesirk et al., 2002; Allman, 2000). Finally, in Example 3 the brain ultimately can *control* the amount of force exerted in a jump (Kandel et al., 2000; Cziko, 1992; Cziko,

1995; Pelligrino, Fadiga, Fogassi, Gallese, and Rizzolatti, 1992).

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 were 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 external to it. 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 (see Arp, 2005a, 2008a, 2008b).

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. Wimsatt (1994, 1997), Zylstra (1992), and Salthe and Matsuno (1995) view the coordination of components as a necessary condition for some thing's being considered as a system.

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 used in diagram 1 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.

This kind of control exhibited in the dual properties of data selectivity and informational integration can be likened to what is referred to in the literature in philosophy of science and philosophy of mind as *downward causation*, whereby a higher-level phenomenon in a system causally influences lower levels. For example, Kim (1993, 1995, 1999) sees downward causation as essential for phenomena described as emergent systems such as organisms and, more specifically, conscious organisms. Further, the property of internal-hierarchical data exchange I have described includes what could be considered *upward causation*, whereby lower-levels in a system causally influences higher levels. For example, part of Emmeche, Køppe, and Stjernfelt's (2000) idea of *inclusiveness* in biological systems entails the emergence of higher-level phenomena—like the biological from the chemical—whereby the biological is still causally dependent upon the chemical. Also, Searle (2004, 1992) continues to maintain his position in philosophy of mind concerning *biological naturalism*, whereby consciousness is not metaphysically reduced, although it is causally reduced, to neurobiology, indicating an upward form of causation (also see Arp, 2004a, 2004b).

5. ENVIRONMENTAL-ORGANISMIC INFORMATION EXCHANGE

Organisms interact with external environments. However, because organisms are hierarchically organized living systems composed of subsystems, processes, and components engaged in various operations, they have their own internal environments as well. An *environment* can be defined as any pressure or force that aids in the producing of some change in the organism's structure and functioning. We can draw a distinction between the information that is exchanged *within* the organism's environment and the information that is exchanged *between* the external environment and the organism. So, there are really two types of environments, viz., environments that are internal to an organism and environments that are external to an organism.

An environment is not limited to the external world surrounding an organism. There are environments internal to the organism. For example, the other organelles, nucleus, ATP, water, and various organic molecules act as the environment for a mitochondrion in the eukaryotic cell. Also, other eukaryotic cells, cancerous cells, water, and all kinds of organic molecules and chemical elements act as the environment for a typical eukaryotic cell. A myriad of molecules including hydrogen, carbon, nitrogen, and oxygen surround and exert influence upon organs in a multi-cellular organism's body. Further, a piece of food taken in from the environment external to the organism becomes part of the environment within the organism and, depending on the content, may be digested or expelled.

These facts concerning internal environmental pressure add to the picture of an organism as a hierarchically organized system. Within this kind of living system, there are levels distinguishable from other levels. One way to describe the distinction is by comparing a certain level, say level(n), with other levels that act as environments exerting pressures, exchanging data, and communicating information with level(n). Once again,

we can refer to the schematization of triangles in diagram 1 that is supposed to represent an organismic hierarchy; however, now the smaller triangles within the one large triangle can be conceived of as situated within the context of internal environments.

At the same time, the organism itself is interacting with external environments that are exerting pressures, exchanging data, and communicating information with the organism. Concerning environments that are external to the organism, we see that organisms are members of species that live in populations. These populations usually co-exist with other populations in communities. Many communities living with their non-living surroundings comprise an ecosystem, and the sum of all ecosystems make up the biosphere of the earth. Other members of a species, different species, and the non-living surroundings of an organism are all considered parts of the external environment for an organism. The organism constantly experiences environmental pressures, and these pressures can be described in terms of information that is exchanged between the environment and the organism.

External environmental information affects an organism in a one-way, environment-to-organism, external-to-internal causal fashion. This kind of information exchange can be witnessed as a result of research accrued and experiments performed by biologists and other thinkers.

It is common knowledge that an organism's survival is dependent upon both genetic and environmental factors. For example, if there is an alteration in a rodent's genetic makeup causing it to have a malformed foot, then it is more likely to be eaten by a hawk out on the open range. However, if the same handicapped rodent lives in a forested area where it can hide under rocks and bushes, it is less likely to become a predator's victim. Also, if an environment happens to be made up of trees having fruit high up on its branches, and it just so happens that a fruit-eating animal's genes coded it to have a neck long enough to reach the fruit, then such an animal likely will survive. Conversely, if your animal genes coded you to have a short neck, it is unlikely you would survive in such an environment (that is, if the fruit high up in the trees were your only food source). In the words of Berra (1990, p. 8): "The environment is the selecting agent, and because the environment changes over time and from one region to another, different variants will be selected under different environmental conditions." These examples illustrate that there is a one-way, external-to-internal exchange of information between an environment and an organism existing in that environment.

Another famous example that illustrates the informational transfer between the environment and an organism in a one-way, external-to-internal fashion has to do with the finches that Darwin (1859) described on the Galapagos Islands during his voyage on *The Beagle*. These finches clearly exhibit *adaptive radiation*, i.e., in the words of Berra (1990, p. 163): "the evolutionary divergence of members of a single phylogenetic lineage into a variety of ecological roles usually resulting, in a short period of time, in the appearance of several or many new species." Darwin noted several different beak shapes and sizes that apparently were modified in the finches, depending upon the ecological niche the particular bird inhabited. Some finches had massive beaks ideal for crushing their seed

food source, others had thinner pointed beaks ideal for probing flowers, still others had curved beaks ideal for picking food out of woody holes. In this set of circumstances, the environments in which the various finches inhabited were all different, and the finches with beaks most fit for a particular environment survived to reproduce.

Phenotypic traits are the physiological characteristics or behaviors of organisms that are under genetic control. The genetic information determines what a particular member of a species will look like, how fast it will run, what coloration it will have, how successful it will be at mating, etc. In the finch example, the different beaks represent the variety of phenotypic characteristics under genetic influence. If it just so happened that a certain beak style was effective in gathering food in an environment, then that finch would survive and pass its genes onto its progeny. Soon, that particular niche would be dominated by the beak style that was most fit for that environment.

Research has been conducted on animals to determine how the external environment affects the functioning of various systems of the body. One experiment has to do with occluding or removing the eyes of cats, rats, and birds at various stages of development to see if the neural connections of the brain necessary to the visual system either would develop abnormally, or cease to function altogether. These studies indicated that when occluding or removing the eyes, certain neural connections in the brains of these animals would not be made. This resulted in the cessation of certain visual processes, causing the overall subsystem to be under-developed in relation to other animals that have not had their eyes occluded or removed (Cziko, 1995). This research illustrates what happens when information *is not* exchanged between environment and organism.

A further example that demonstrates environment-to-organism, external-internal information exchange has to do with research on the fruit fly, *Drosophila*. Experimenters are able to take out, move around, or add genetic sequences in the DNA of the fly, causing radical phenotypic alterations to result such as the deletion of some organ, legs growing where antennae should be, and antennae growing where legs should be. The experimenter's adjustments to the genetic code of the fruit fly are analogous to the radioactive material and other kinds of natural external forces of mutation that alter the genetic codes of fruit fly populations. We find similar monstrosities in fruit flies when we study them in their natural habitats (Duncan, Burgess, & Duncan, 1998). Just as researchers tap into and alter the genetic codes of fruit flies in controlled experiments, so too, external forces "tap into" and alter the genetic makeup of fruit fly populations in nature. These fruit fly abnormalities are another example of the property of environmental-organismic information exchange found in organisms.

6. ORGANISMS, EMERGENCE, AND REDUCTION

The attempt has been made to show that the processes in which the components of an organismic hierarchy are engaged produce homeostasis through abilities to internally exchange data, selectively convert data to information, integrate that information, and process information from environments. Now, it will be argued that the components and

attending processes of an organism must be considered as living, emergent phenomena because of the way in which the components are organized to maintain homeostasis of the organism at the various levels in the organismic hierarchy. Near the end of section 1, the claim was made that higher-level subsystems are the phenomena that literally *emerge* from lower-level subsystems and processes of an organism conceived of as a hierarchically organized living entity. With respect to organisms, certain forms of metaphysical and epistemological emergence will be endorsed in this final section of the paper.

As Silberstein (2002, 2001), Silberstein and McGreever (1999), and McLaughlin (1992) have clarified, there are metaphysical and epistemological forms of emergentism. According to metaphysical emergentists, entities, properties, or substances arise out of more fundamental entities, properties, or substances and yet, are not wholly reducible to them. In Kim's (1995) words: "a property of a complex system is said to be 'emergent' just in case, although it arises out of the properties and relations characterizing simpler constituents, it is neither predictable from, nor reducible to, these lower-level characteristics" (p. 224; also see the discussions in Kim, 1999; Wimsatt 1994, 1997; Emmeche, Køppe, and Stjernfelt, 2000; Craver, 2001; Lowe, 2000; McLaughlin, 1997; O'Connor, 1994; Rueger, 2000; and Zylstra, 1992). According to epistemological emergentists, the concepts, theories, models, or frameworks we utilize to describe phenomena at a certain level are non-reducible to the concepts, theories, etc., at a lower level (see, for example, the discussions in Batterman, 2001; Cartwright, 1999; Primas, 1998; Sklar, 1999; Dupré, 1993; Crane, 2001; and Van Gulick, 2001).

Further, as Silberstein (2002) and Silberstein and McGeever (1999) clarify, within the genera of metaphysical emergence four kinds have been distinguished, viz., non-elimination, non-identity, mereological emergence, and nomological emergence. Also, within the genera of epistemological emergence, at least two kinds of approaches have been distinguished, viz., predictive/explanatory emergence and representational/cognitive emergence. In light of the previous sections of this paper, the metaphysical and epistemological forms of emergence that will be explored and defended in this section are:

1. Nomological Emergence, understood by Silberstein (2002) as "cases in which higher-level entities, properties, etc., are governed by higher-level laws that are not determined by or necessitated by the fundamental laws of physics governing the structure and behavior of their most basic physical parts" (p. 91).
2. Representational/Cognitive Emergence, understood by Silberstein (2002) as the thesis that "wholes (systems) exhibit features, patterns or regularities that cannot be fully represented (understood) using the theoretical and representational resources adequate for describing and understanding the features and regularities of their more basic parts and the relations between those more basic parts" (p. 92).

From the metaphysical perspective, nomological emergentists deny the general principle that the whole can be accounted for fully in terms of the parts, and so their

view is contrasted with *nomological reductionism*. According to nomological reductionists, 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 reality of an entity, property, or substance. So for example, when people speak about water, they may take it to be a substance in its own right. However, according to the nomological reductionist, water *just is* hydrogen and oxygen – nothing new emerges when two hydrogen molecules combine with one oxygen molecule. Conversely, according to a nomological emergentist there is something about water, e.g., its liquidity or liquid property, that emerges from the hydrogen and oxygen molecules, making it such that this liquidity exists on a separate metaphysical plane from the molecules on which it depends. After all, reason nomological emergentists, liquidity appears to be something distinct from hydrogen and oxygen molecules, as well as their chemical bond.

From the epistemological perspective, representational emergentists are contrasted with representational/theoretical reductionists who attempt to reduce concepts, theories, etc., 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. So if we took the cell as an example, according to a representational reductionist the cell *can be described* completely within a physico-chemical framework of concepts, theories, models, laws, etc. (see the discussions in Churchland, 1995; Humphreys, 1997; Primas, 1998). Issues surrounding epistemological emergence and reduction 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 epistemological emergence accepts or implies that biological descriptions may emerge that are not reducible, even in principle, to physico-chemical descriptions. 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?

7. THE HOMEOSTATIC ORGANIZATION VIEW OF BIOLOGICAL PHENOMENA

Some emergentists maintain that chemical bonds or basic physical structures – as well as our descriptions of them – are non-reducible to the molecules and atoms of which they are composed. So, there is an emergence-reduction divide even at the physico-chemical level (see, for example, the discussions in Hendry, 1999; Hellman, 1999; Belot and Earman, 1997). This physico-chemical debate is avoided here, and instead I maintain that *starting with the organelles that constitute a cell*, and continuing up the hierarchy

of components in processes and subsystems of an organism, we have clear instances of living, emergent biological phenomena. The fundamental reason why 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 maintain homeostasis of the organism* at the various levels in the hierarchy. I call this position the *homeostatic organization view* (HOV) of biological phenomena. Since homeostasis is ubiquitous as both a *concept* and as a *recognized reality* in biological, psychological, and philosophical communities (among many other disciplines), it makes for a natural point of discussion in the emergence/reduction debate.

In section 1, a distinction was drawn between particularized homeostasis and generalized homeostasis. It was shown 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 environment external to it (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 was noted 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), Kandel, Schwartz, and Jessell (2000), Voet, Voet, and Pratt (2002), Campbell and Reece (1999), 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. Recall all of the information being exchanged between and among the organelles of an animal cell spoken about and schematized in diagram 3 a few pages back. The nucleus is in constant communication with each mitochondrion, centriole, golgi apparatus, ribosome, and endoplasmic reticulum, each of which has its own function in maintaining the overall homeostasis of the cell.

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 living, emergent entities.

Referring to the schematization of an organism as one huge triangle containing smaller triangles that was used in section 1, each one of those triangles—from biggest to smallest—represents a biologically emergent phenomenon. For example, although the organelles of a cell 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 of the mammal (see the final section of Kaneto, Morrissey, McCracken, Reyes, and Klahr, 1998).

8. PSYCHOLOGICAL EMERGENCE (BRIEFLY)

What about emergence at the psychological level? 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 (for starters, see Kim, 1993, 2000; Lycan, 1995; Crane, 2001; Churchland, 1995; Buss, 1999; Cosmides and Tooby, 1994; Roth, 2000; Arp, 2007a, 2007b; Arp and Terzis, 2008c). Given space limitations, the subject merely can be glossed here. It is arguable that the psychological realm is an extension of the neurobiological and biological realms, and that mental states are emergent phenomena that are, in many ways, subject to the same laws as any other neurobiological and biological phenomena. More than a quarter of a century ago, Sperry (1980) stated the position eloquently, noting that a psychological phenomenon is a “functional property of brain processing, constituted of neuronal and physicochemical activity, and embodied in, and inseparable from, the active brain” (p. 204). Just as cellular processes exhibit internal-hierarchical data exchange, data selectivity, informational integration, as well as exchange of information with environments, so too, neurobiological and psychological processes exhibit analogously similar kinds of properties (also see Arp, 2005b, 2007a, 2008a, 2008b). It has been 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 maintain 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. 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 (also see Arp and Terzis, 2008). 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 physico-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 maintain generalized homeostasis of the organism.

Now, in arguing for HOV I am not advocate some “spooky stuff” principle (this terminology is borrowed from Churchland, 1993) of internal “vitalism” or external

“design,” the likes of which might be put forward by an organicist or a creationist (see Arp, 1998, 2002, 2007b). As was mentioned earlier, the property of internal-hierarchical data exchange in an organism manifests upward causation, whereby the lower levels of the hierarchy exhibit causal influence over the higher levels. Likewise, the dual properties of data selectivity and informational integration manifest downward causation, whereby the higher levels of the hierarchy exhibit causal influence over the lower levels, in terms of control. 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.

Now, think of all of the complex upward and downward causal relations taking place when the human body simply gets up out of bed. Put crudely, the brain must exhibit downward causation, as a necessary condition, upon its own neuro-chemical constituents in order to cause the body to get up; while the neuro-chemical constituents must exhibit upward causation, as a necessary condition, for movement to occur in the first place. There is no “spooky” vitalism or design in any of this upward and downward causal interaction.

9. MORE THAN MERE MECHANISM

HOV adds an important addition to one standard interpretation of a hierarchical mechanism. As was mentioned already, Craver’s (2001) description of a mechanism hierarchy as some mechanism S , which is Ψ -ing, composed of smaller entity X s, which are Φ -ing is commonplace in the literature. These X s are little mechanisms themselves consisting of smaller entity P s, which are σ -ing. This view has the benefit of describing some mechanism as a hierarchically organized system, in a non-spooky fashion, consisting of entities engaging in inter and intra-leveled causally-efficacious activities. In fact, Craver’s view of a hierarchical mechanism maps onto my schematization of a hierarchically-organized system envisioned as nested triangles, and our two views have much in common.

However, the problem with his view of mechanisms is that it neglects the more specified kinds of organized homeostatic activities in which the processes of organismic hierarchies are engaged. It is arguable that physico-chemical entities – the so-called smaller entity P s, which are σ -ing that make up the organelles, which are Φ -ing –

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 homeostatic manner*. Further, it is arguable that 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.

Organisms are responsive to their environments in such a way that they can adapt to changes. A callous on your foot is a simple example of the endocrine subsystem of your body adapting to a change in its external environment. Organisms, as well as the subsystems and processes of which they are composed, exhibit a certain amount of flexibility and malleability in relation to their internal and external environments. In fact, as we have already seen, the subsystems and processes of organisms produce particularized and generalized homeostasis, viz., a relatively constant coordination among the components of an organism, given the interaction of these components with environments internal to and external to the organism. As was intimated already, this property of adaptability in relation to environments that is yet another essential feature that distinguishes living entities, properties, or substances from nonliving ones. Another way to say this is that the adaptability of processes and subsystems in organisms can be pointed to as a clear way in which to distinguish the biological from the physico-chemical realms.

Think of a rock. A rock would be classified as a nonliving, physico-chemical entity because it does not have this ability to adapt to environments and situations the way in which living, biological entities do. If a rock is hit by a hammer with a certain amount of force, it breaks up into pieces, the pieces fall where they may according to physico-chemical laws, and that is the end of the story—this is its “response” to the environment. Conversely, if one’s forearm is hit by a hammer such that a bone breaks, the various systems of the body go to work to repair the damage so that some form of homeostasis can be re-achieved. The body *adaptively* responds to this environmental pressure, and the hierarchy goes to work on fixing the problem.

Further, if the bone does not heal correctly or the muscles surrounding it have atrophied because of the blow, the subsystems and processes of my body can compensate for the injury. If the hierarchy can’t fix the problem, it adjusts or re-adjusts, if necessary. Homeostasis in an organism *entails* adaptability as a necessary condition; for it is the organism’s response to its ever-changing environment that will occasion the need for either particularized or generalized homeostasis. Of course, biological entities are constructed of physico-chemical components and are subject to the same physico-chemical laws as any other piece of matter in the world. However, biological entities, as hierarchically organized living systems, have this distinguishing property whereby the subsystems and processes adaptively respond to their environments in ways that other physico-chemical entities do not.

10. EPISTEMOLOGICAL EMERGENCE

So far, a metaphysical form of emergence has been argued for whereby parts of a biological system are envisioned as genuine emergent entities, starting at the level of the organelles of the cell. A question may arise as to how it is that a corresponding epistemological form of emergence may be possible so as to describe the metaphysically emergent biological phenomena (also see Arp, 2004a, 2004b). This question of the relationship between metaphysical and epistemological forms of emergence is central to any discussion of emergence/reduction as it would seem difficult to justify ontological claims without appealing to epistemological claims, and vice versa. Given this intimate relationship between metaphysics and epistemology, it may be that once a particular ontic level has been identified as emergent, then a whole new set of concepts, theories, etc., will have to be introduced to account for the emergent phenomena.

The HOV endorsed with respect to the functioning of organisms can be described within a biological framework that utilizes the language of teleology/functionality. Thankfully, this kind of language already is being used by biologists, psychologists, philosophers, and other researchers to describe biological phenomena (for example, see the essays in Ariew, Cummins, and Perlman, 2002; Arp, 2006b; Arp and Ayala, 2008; Arp and Rosenberg, 2008)). As Ruse (2004) has pointed out, researchers thinking about biological matters since Aristotle cannot get around using the concepts and language of purpose, function, and organization to describe biological phenomena, even if to describe this phenomena *as if* it were teleologically organized. *That* researchers cannot get around describing biological phenomena *as if* it were organized with goals toward homeostasis may already be an indicator of an epistemological form of emergence. Our descriptions of biological phenomena resist a reductive explanation to the levels of chemistry or physics. If one adopts a realist strategy for describing biological phenomena, or an *as if* realist strategy (see Rescher, 2005; Arp, 2005c, 2005d), then it is easy to see how one could connect an epistemological form of emergence with a metaphysical form. Here, the descriptions of biological phenomena resist reduction, and must be *described* with a set of emergent terms, precisely because that is the way biological phenomena *actually are* homeostatically organized out there in the world. This may be why we cannot seem to jettison the language of teleology/functionality from our vocabulary.

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 *underdescribing* 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 a description of a dog's kidney, for example, than can be captured by the language of 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.

II. CONCLUSION

I have argued that starting with the organelles that constitute a cell – and continuing up the hierarchy of components in processes and subsystems of an organism – there are clear instances of emergent biological phenomena that can be considered “living” entities. I put forward HOV as way to interpret the fact that the components and processes of an organism are organized to maintain homeostasis of the organism at the various levels in the hierarchy. That components of biological phenomena are organized to perform some function resulting in homeostasis marks them out to be living emergent entities distinguishable, in description and in reality, from the very physico-chemical processes of which they are composed. I described internal-hierarchical data exchange, data selectivity, informational integration, and environmental-organismic information exchange in order to proffer HOV. Finally, I demonstrated that HOV comports well with the standard philosophical accounts of nomological and representational emergence. Hopefully, I have made a minor contribution to the debate concerning what constitutes a living entity.

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