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The Homeostatic Structure of Macroscopic Behavior

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The structure of behavior is studied in genes, cells, tissues, organs, organ systems, and the brain, using vectors that express the direction of response from inside each system to outside the system. As a system changes to a different state from its original state, the changed system is included outside the original system, and the behavior from the original system toward the changed system is described by one vector. It has been thought that behaviors in genes and cells have bidirectional vectors originating from each system that point toward both their changed and unchanged state and that behaviors in the subcortical and cortical brains increase the directions of their vectors to multidirectional ones proportional to the increase of nerves in the organism. Further, it has been suggested that the differentiation of the brain is related to the expensive differences of mediators in the regulatory organ system, where the wastes of mediators are reduced from immune cells in the immune system and protein hormones in the endocrine system to electronic impulses in the autonomic nervous system.

Keywords: behavior, vector, homeostasis, cell, consciousness

There are states that change a phenomenon, and such a phenomenon corresponds with a response that is brought by a kind of "black box." A black box is "open" when the box interacts with its surroundings, and an open black box may maintain a constant content. A constant open black box requires boundaries, reactions, and regulations to ensure that the box makes its efflux to the environment equal to the influx from the environment to maintain its constant state as a homeostatic system (Ganong, 2005, pp. 7, 48; Nelson and Cox, 2008, pp. 570–571). Genes, cells, tissues, and organs are similar to the homeostatic system with macroscopic boundaries, microscopic reactions, and feedback regulations. It seems that each such homeostatic system has the common structures of recognition, logic, emotion, and behavior. In this study, the structure of behavior in each homeostatic system is explored.

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Behavior is one of the responses to an environment outside a system and is expressed by a vector composed of direction and magnitude. A vector for the behavior of a system is described by an arrow pointing from inside a system to outside. It is presumed that the system that has changed from its original state to a different state is included outside of the original system and is described as the target of one vector. And the original system that has not yet changed to a different state is also included as the target of one vector with only magnitude and with no direction like a scalar, even though the system moves spatially with the same state. But microscopic interactions between a system and others are excluded from the vector count of macroscopic behavior because they are related to the innumerable changes of the original system to be described by countless vectors, while the macroscopic effects of a system on other systems or the environment also become countless behaviors. Therefore, the behavior of a system is described as a macroscopic vector from the original system to the microscopically changed original system including the microscopically unchanged original system.

Genes make replicas from the template of an original DNA through a process called replication (Watson, Baker, Bell, Gann, Levine, and Losick, 2008, pp. 132, 195). Parental DNA forms complementary daughter DNA due to the self-coding nature of a DNA molecule between two bases, i.e., adenine and guanine on one DNA chain with thymine and cytosine, respectively, on another DNA chain. Though packaging DNA into chromosomes is to form a kind of boundary in order to alter the accessibility to DNA and protect it from damages, packaged DNA also coordinates recombination, in which chromosomes pair prior to the first nuclear division and the partial changes of DNA occur between chromosomes, to modify gene expression in order to create diversity at the right time and in the right place (Watson et al., 2008, pp. 96, 283, 315–316). In fact, every DNA is recombinant DNA. And the recombination allows cells to retrieve partially lost DNA by replacing the damaged section with an undamaged DNA section. The organism can survive only if its DNA is replicated and is protected by feedback regulation from various damages that would change its coding properties, whereas genetic variations are needed to drive evolution; in other words, new species would not arise if the genetic material showed perfect fidelity perpetually (Watson et al., 2008, pp. 96, 257, 281). Therefore, genes are subject to two sustainable processes: one that ensures that DNA molecules remain unaltered from generation to generation, and the other that brings about partial changes in the genetic material to drive the next generations to diversity and evolution. Thus, there are two possible directions of the vector with respect to the behavior of a gene, where either the gene does not change itself to succeed as the original system or it changes itself to succeed as its descendent system.

Eukaryotic cells have membrane-bound microscopic compartments called organelles such as endoplasmic reticulum, mitochondria, and lysosome, which provide energy and degrade cellular components in the macroscopic boundaries

of cell membranes (Pollard and Earnshaw, 2008, pp. 313–314, 346). The endoplasmic reticulum synthesizes proteins and lipids for its cellular and extracellular constitution, while mitochondria produce ATP in the form of energy for diverse cellular functions. And continuous degradation by lysosomes or proteasomes occurs as a turnover in order to replace older molecules with newly synthesized ones or as a repair in order to remove damaged molecules so that they do not hinder the functions of native molecules (Pollard and Earnshaw, 2008, pp. 409, 412–413). This process of degradation and replacement serves the activation of the cell cycle or the remodeling of a cell in development. Meanwhile, genetic changes in a series of cell cycles that lead to DNA replication or cell division may also lead to an uncontrolled proliferation of cells such as cancer (Pollard and Earnshaw, 2008, pp. 731, 733, 753). However, the genetic alterations that are required to transform a normal cell into a cancerous one are remarkably rare, because the cell cycle is highly regulated by feedback check points that ensure appropriate cell cycle progression. Further, the programmed cell death of apoptosis, which is physiological cell death against pathological cell death, is important for embryonic development, homeostatic maintenance in tissue, immune self-tolerance, and hormonal regulation in cell viability (Pollard and Earnshaw, 2008, p. 833). Thus, it is understood that a cell works to maintain the present system and also works to give birth to the next generation despite its death, that is, the behavior of a cell follows the structure of bidirectional vectors pointing toward itself and its descendant in order to succeed its homeostatic system.

A tissue consists of similar cells, and four types of tissues exist: epitherial, connective, muscular, and nervous, and then these tissues make up all the organs, that is, most organs contain all four tissue types (Marieb, Mallatt, and Wilhelm, 2008, pp. 3–4). Epithelial tissue covers the surfaces of most organs; connective tissue supports and protects all organs; muscular tissue provides the movements of most organs; and nervous tissue transmits electrical signals to most organs, while each organ acts as the specialized functional center responsible for the ability that no other organs can perform. Further, cell surface adhesion proteins enable cells to establish intimate relationships with each other and with the extracellular matrix, and these cell–cell and cell–matrix interactions are essential for maintaining tissue integrity and intercellular communication in complex tissues and organs (Pollard and Earnshaw, 2008, pp. 515–516). And a limited repertoire of adhesion proteins allows cells in multicellular organisms to establish specific interactions with appropriate partner cells or avoid inappropriate interactions. This selective specificity is required for the formation of epithelia, the assembly of connective tissue, the transmission of force to the extracellular matrix in muscle contraction, and the healing of wounds through immune regulation. Furthermore, a remarkable variety of cells in connective tissue manufactures an extracellular matrix, which does not only become mechanical support and defense for epithelia, muscles, and nerves as a macroscopic boundary but also enables cellular migration for immune

responses and provides the communicating routes of essential signals in feedback regulations for survival and growth (Pollard and Earnshaw, 2008, pp. 517–518, 531, 583). Tissues consist of stem cells as well, which have the capacity to produce cells that remain as stem cells or those that can differentiate into specialized cells as asymmetrical cell division (Pollard and Earnshaw, 2008, pp. 757–758). This asymmetrical cell division means bidirectional cell divisions both toward one daughter stem cell for further proliferation and toward another committed cell for differentiation into tissue cells though general symmetrical cell division results in two daughter cells only for further proliferation. Thus, the structure of behavior in a tissue or an organ can be described by bidirectional vectors pointing toward the specialized differentiations and toward the unchanged stem cells, thereby maintaining each homeostasis.

Organs that work closely together with a common purpose constitute an organ system, such as the cardiovascular organ system that contains the heart and blood vessels and is responsible for transporting blood to all body tissues (Marieb et al., 2008, pp. 4–5). Other examples include the digestive organ system containing stomach and intestines, which breaks down food and helps in absorbing nutrients; and the respiratory organ system containing trachea and lungs, which transports oxygen and exchanges oxygen with carbon dioxide. It is proposed that each organ system can be further regarded as collective organ systems, i.e., the metabolic collective organ system including the digestive and respiratory organ systems, the circulatory collective organ system including the cardiovascular and urinary organ systems, the connotative collective organ system including the integumentary and reproductive organ systems, and the denotative collective organ system including the motor organ system and the central and somatic nervous systems. Interestingly, each metabolic, circulatory, connotative, and denotative collective organ system in the organism is respectively similar to organelles, cytoplasm, membranes, and receptors in a cell, if we consider that the organism is maintained by these collective organ systems as well as the homeostasis of a cell is kept by these corresponding microscopic structures. Is there another collective organ system in the organism that is analogous to feedback regulation in the homeostatic system of a cell? The immune system, endocrine system, and autonomic nervous system are categorically left by subtracting the metabolic, circulatory, connotative, and denotative collective organ systems from all organs in the organism. Is there one more collective organ system that specially regulates other collective organ systems? The immune, endocrine, and autonomic nervous systems may be regarded as one of the collective organ systems for the regulation of the total organism and can be called the regulatory organ system.

Many defense cells are present in or migrate to connective tissue that covers all organs, and lymphoid organs produce and store various immune cells to fight against invading microorganisms at the main "battle field" of connective tissue (Marieb et al, 2008, pp. 84, 605). In detail, macrophages that are phagocytic cells

of the immune system are activated by cytokine interferon-gamma, which is produced by T (thymus-derived) lymphocytes to trigger inflammation for killing bacteria, while macrophages respond to the correspondent cytokine interleukin (IL)-4 produced by other T lymphocytes to limit the inflammatory reaction (Kumar, Abbas, Fausto, and Aster, 2010, pp. 54, 184–185, 195, 211). Helper T lymphocytes of the adaptive immune system secrete IL-1 and IL-6 to stimulate B (bone marrow-derived) lymphocytes for neutralizing microbes or toxins, while as immunological intolerance, regulatory T lymphocytes that are mediated by correspondent IL-10 inhibit the activation of other lymphocytes that accidentally attack its host as one of the antigens called self-antigen. Thus, the immune system operates on the connective tissue that develops throughout the whole body, and works with the basal level of immune cells or protein cytokines far from the functional centers of differentiated organs, and regulates the defense for other organs through the correspondent signaling of cytokines.

The endocrine organs that arise from three embryological germ layers are widely distributed to numerous organs including hormone-secreting neurons, muscle cells, and fibroblast cells (Marieb et al., 2008, pp. 753, 768). Hormones that are produced by endocrine glands enter nearby capillaries through the extracellular matrix of connective tissue to travel toward specific targets and signal most organs to respond in a certain characteristic way. For instance, the thyroid gland, adrenal cortex, and gonads are stimulated by hormones from the pituitary gland, while the pituitary gland is correspondently inhibited by feedback hormones from each target organ (Ganong, 2005, pp. 327, 375, 432; Marieb et al., 2008, p. 77). Therefore, the endocrine system influences the metabolism and growth of most tissues and organs, and works with the basal level of protein or steroid hormones, and regulates other organs through the correspondent signaling of hormones.

Nerves are surrounded by three layers of connective tissue that correspond with the three layers of connective tissue in skeletal muscles (Marieb et al., 2008, pp. 240, 360). The autonomic afferent pathway has few receptors for the sense of pain or temperature in visceral organs, while the autonomic efferent pathway is not easily controlled by consciousness, and thus the autonomic nervous system is relatively independent from the central nervous system (Ganong, 2005, p. 143; Marieb et al., 2008, p. 459). Further, the autonomic sympathetic and parasympathetic nervous systems innervate glands and smooth muscles to regulate visceral functions so that the efferent nerves with neurotransmitters like noradrenalin or acetylcholine can control digestion, respiration, urination, and blood pressure, which are essential for maintaining the stability of the body's internal environment, while the afferent nerves continuously monitor the activities of visceral organs so that the efferent nerves can make adjustments as necessary to ensure the optimal performance of visceral functions, utilizing the antagonistically correspondent relationship between sympathetic and parasympathetic nervous systems (Marieb et al., 2008, pp. 459–460). Therefore, the autonomic nervous system operates on most visceral

organs, and works with the basal level of monoamines or impulsive electrons, and regulates other organs through the correspondent signaling of impulses.

The immune, endocrine, and autonomic nervous systems regulate other organs to maintain the total organism. These systems have some similar elements. First, they extend to the whole body along connective tissue. Second, they are located below the subcortical brain. Third, they are mainly derived from neural crest and branchial arch at approximately the same time in early embryos (Sadler, 2012, pp. 67, 69, 262, 267). Fourthly, they function at the basal level near to the cells far from other differentiated organs with muscles. Fifthly, they operate the original signals of each system. And sixthly, their regulations are performed through correspondent feedback loops. Therefore, the immune, endocrine, and autonomic nervous systems that are congruent with each other must be regarded as one of the collective organ systems, called the regulatory organ system — in addition to other four collective organ systems. And there may be the regulatory organ system at the basal level of the organism below the central nervous system for the regulation of the whole body through correspondent feedback mechanisms with the original signals, which substantially show a subconscious state in the living things just like a "mind." Hence, the structure of behavior in the regulatory organ system can be described by bidirectional vectors pointing toward the correspondent change of the original regulatory organ system for the total homeostasis of the organism beside the unchanged original mind.

If the regulatory organ system behaves with the necessary direction and sufficient magnitude of a vector, every other organ is well controlled and then the whole body is easily maintained. But an organism becomes hard to be maintained when the regulatory organ system loses its balance with respect to the regulatory mediators of immune cells, endocrine hormones, and neuronal impulses. The autonomic nervous system mainly uses impulsive electrons to lessen the sacrifice of its mediators for the regulatory organ system in comparison with the sacrifice of immune cells in the immune system or protein hormones in the endocrine system. As a result, vector quantity in the behavior of the autonomic nervous system is smaller than one in the behavior of the immune or the endocrine organ system. The regulatory organ system may have evolved from the adrenergic "vegetative" endocrine system that wastes expensive protein to the sympathetic "animal" nervous system that consumes dispensable electrons. Further, the regulatory organ system must have differentiated toward being a more efficient and diverse system in order to respond to the dynamic change of nature outside the body. The nervous system, including sympathetic nerve, can more easily alter the direction and the intensity of the vector in the behavior of the regulatory organ system. It is assumed that the regulatory organ system has become biased to the differentiation of the nervous system, that is, the central nervous system.

After the basal ganglia receive inputs from the cerebral cortex, the ganglia select the appropriate muscles and inhibit the relevant antagonistic muscles in

their involuntary and unconscious adjustments, though the ganglia also participate in repetitive learning to develop subconscious habits (Ganong, 2005, p. 202; Marieb et al,. 2008, pp. 402–403, 414). The cerebellum first receives information on the movements being planned by the cerebral cortex, and next, the cerebellum compares this intended information with the actual movement that is fed back through afferent proprioceptive nerves, and then the cerebellum sends its instructions back to the cerebral cortex on how to resolve any differences between the intended and actual movements, and finally the cerebral motor cortex readjusts its motor commands and sends a fine-tuning order so that the movement is well coordinated and smoothened (Ganong, 2005, pp. 202–203; Marieb et al,. 2008, pp. 389, 414). The red nucleus in the midbrain receives inputs from the cerebellum to bring about the involuntary and unconscious flexion of limbs (Marieb et al,. 2008, pp. 386, 414). Thus, the basal ganglia or cerebellum forms compound feedback circles across the cerebral cortex or red nucleus, often through the thalamus and reticular formation, to exert the involuntary and automatic reflexes of neuronal impulses as subconscious behavior in the subcortical brain so that the organism can more efficiently adjust complex stimuli from the environment. The basal ganglia, cerebellum, thalamus, and combined brain nuclei are differentiated at approximately the same time after the generation of the autonomic nervous system (Sadler, 2012, pp. 300, 305). The immune system, endocrine system, and parasympathetic nervous system are associated with the hypothalamus below the subcortical brain both as part of the "vegetative" system and as part of the "animal" system. In contrast, the sympathetic nervous system, motor nervous system, and sensory nervous system are organized with the thalamus, basal ganglia, and cerebellum around the subcortical brain only as part of the "animal" system. Hence, the structure of behavior in the subcortical brain can be described by the vectors of proper numbers in linear function with appropriate direction and magnitude pointing toward the efficient changes of the original instinct for the subconscious adaptation of an animal.

Neurons of the cerebral neocortex are mostly pyramidal cells with one efferent long axon and many vertical dendritic trees, and the efferent axons usually give off recurrent collaterals that turn back on the dendritic trees of other pyramidal cells (Ganong, 2005, p. 192). Pyramidal cells in the cerebral neocortex reciprocate information with each other to perform reference, comparison, conformation, and selection for the total organism owing to their serial and parallel relations or their diverging and converging associations with repeatable feedback correlation (Marieb et al., 2008, pp. 363–364, 400). The posterior association area extracts symbolic patterns from subjective representations in the primary and secondary sensory areas for abstraction, and then the angular gyrus (Brodmann area 39) processes the abstracted patterns into abstracted meanings and sends them to Wernicke's area, while Wernicke's area, which coordinates abstracted meanings to categorize them as objective concepts in order to present language

to society, projects onto Broca's area, and then Broca's area processes abstracted meanings or categorized concepts and projects them onto premotor cortex for gestures or vocalizations (Ganong, 2005, pp. 273–274; Marieb et al., 2008, pp. 400-401). The prefrontal cortex, which is the large region of frontal lobe, receives abstracted meanings from the sensory association cortex or categorized concepts from Wernicke's area and then integrates these meanings and concepts with the past experience that is intentionally remembered through the limbic system. The subject of the association cortex, which objectifies the subject itself as a different object from other objects, can objectively recognize its intended movement as a voluntary behavior, and then the subject can objectively recognize the subject itself as a "self." The function of the neocortex that objectively represents its recognition, logic, emotion, and behavior as the subject of its self may be called "consciousness," and its voluntary intention must be called "will." Therefore, it seems that consciousness selects will with the largest degree of freedom in each self and then liberty originates in consciousness. Thus, the structure of behavior in the cortical brain can be described by the multidirectional and multi-intensive vectors of unlimited numbers in exponential function as a free will that tries to behave toward the diverse changes of the original consciousness for the conscious creation of a human being.

It seems that there are two axes in the structure of a self, though a self is the theme that has been sought by Greek philosophy or Zen Buddhism. One axis is the horizontal structures of recognition, logic, emotion, and behavior that construct a self in each homeostatic or differentiated system. Another axis is the vertical phases of a cell, the organ system, the subconscious brain, and consciousness that construct a self in each life. Therefore, the behavior of a life has been explored as one of the structures of a self, and then it has been shown that the direction of macroscopic behavior is increased by the disposable mediators of a neuron from the regulatory organ system of subconscious mind to the brain of consciousness.

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