The Journal of Mind and Behavior
Summer and Autumn 2024, Volume 45, Numbers 3 and 4
Pages 251–258
ISSN 0271–0137

The Homeostatic Structure of Emotion

Koshi Otsuka

Yokohama City, Japan

The structure of emotion is one of the microscopic reactions in the macroscopic systems of a cell, an organ, the organ system, and the brain — though the structure of logic is another of the microscopic reactions with feedback regulations among them. In this study, gradient and threshold are explored in the boundaries between each system and the environment as the barriers to be overcome by emotion for behavior to occur. It has been thought that the resistance of transmembrane gradient and the energy of ATP are the prototypes of emotion in the homeostatic system of a cell. Further, it is suggested that the origin of emotion is hidden in the tautomerizing predominance of nucleic acids that pair with other ones, keeping equilibrium in a gene.

Keywords; homeostasis, threshold, ATP, emotion, consciousness

A homeostatic system has microscopic — low molecular compound — reactions and regulations with a macroscopic — high molecular compound — boundary in the environment in order to balance the system's influx and efflux of energy or material to keep its equilibrium (Ganong, 2005, pp. 7, 48; Nelson and Cox, 2008, pp. 570–571). Therefore, it is thought that a life is a homeostatic and homeodynamic system that is microscopically trying to maintain its macroscopic body. The macroscopically homeostatic and microscopically homeodynamic system of life receives a stimulus from the environment as recognition to make microscopic reactions and regulations for the macroscopic response of behavior. And the macroscopic boundary of a homeostatic system is a kind of barrier that resists against the diffusion of microscopic molecules between the system and the environment with gradient or threshold. Then it seems that there are two structures in microscopic reactions for the macroscopic behavior of a homeostatic system, that is, one is an indirect structure through the microscopic regulation of feedback logic and another is a direct structure without the logic.

Correspondence concerning this article should be addressed to Koshi Otsuka, 4–14 Yamate-cho Naka-ku, Yokohama City, Japan Email: koshi_o_t@yahoo.co.jp

A homeodynamic system reacts microscopically through feedback logic to clear the threshold of a barrier between the macroscopic system and the environment toward behavior on one hand. A homeodynamic system reacts microscopically without logic to break the barrier on the other hand. Is not the macroscopic barrier of a homeostatic system to be overcome by its microscopic reaction with no feedback logic concerned with the formation of emotion?

Programming for the formation of emotion will be advanced in artificial intelligence (AI). However, the fulfillment of this programming means that AI gets the emotion by which human consciousness is inclined to make a mistake in its logical judgement on account of emotional excitement or depression. That AI makes a mistake owing to its emotional influences is inconsistent with a computer being needed for fast and correct calculation. What are microscopic reactions corresponding to the phenomena of emotion in the homeostatic system of a cell and its differentiated systems of the regulatory organ system or the brain?

A cell has a lipid membrane that is impermeable to ions or macromolecules, and this impermeability makes it possible for the cell's plasma membrane to form a barrier between its cytoplasm and the environment (Pollard and Earnshaw, 2008, pp. 111, 167–168). Proteins embedded in a lipid membrane facilitate the movements of ions or other solutes across the membrane, and these proteins, called pumps and channels, selectively transport macromolecules through their pores to allow a cell to make an internal environment different from the external one. Further, an impermeable membrane provides the resistance required to separate charges across its surface. Namely, both pumps and channels produce unpaired charges across their membranes. Then this charge imbalance arouses membrane potential. The pumps that transport unpaired ions generate membrane potentials directly, while the channels that selectively pass unpaired ions can use ion concentration gradients across membranes to generate membrane potentials. At last, the force produced by membrane potential influences the diffusion of ions through the pore of a cellular membrane in both directions to balance its cytoplasm against the environment as an equilibrium. Thus, a cell has the gradient of potential across its boundary as a barrier for its homeostasis.

Nutrients with high-energy bond like CO_2 or carbohydrate are degraded by enzymes, which stabilize the high-energy transition state for chemical reactions, to reach to the production of adenosine triphosphate [ATP] (Pollard and Earnshaw, 2008, pp. 63, 332, 342; Watson et al., 2008, pp. 60–61, 63–64, 69). And organic larger molecular products like polypeptides or polynucleotides are synthesized as the new constituents of a cell from the degraded elements that are activated by ATP in order to facilitate various reactions. ATP provides the other energy that is required for the movement of small molecules across a cellular plasma membrane against its electrical gradient, though ATP is liberated as heat energy in a cell when it is hydrolyzed (Pollard and Earnshaw, 2008, pp. 9, 128). All living species use ATP that is synthesized at mitochondria for many energy-requiring reactions in a cell, since mitochondria appeared 2 billion years ago when α proteobacterium — the origin of mitochondria — fused with the archaeal cells from which eukaryotes branched apart from prokaryotes (Watson et al., 2008, pp. 4–5, 14, 23, 331). Thus, ATP with high energy drives microscopic reaction at a cell's membrane against the transmembrane gradient to clear the macroscopic barrier. Additionally, ATP produces heat by its hydrolysis in every cell. Therefore, it is thought that a cell is loaded with the resistance of membrane to be overcome by ATP with heat, which may be the prototype of emotion. Hence, a cell has emotion with load and energy for behavior.

Is there any barrier that corresponds to the formation of emotion in a tissue and in an organ? Every organ is composed of four tissues — epithelial, connective, muscle, and nervous tissues, and the specialty of an organ is determined by the proportion of each tissue because the function of each organ is accomplished by the combination of each tissue (Marieb, Mallatt, and Wilhelm, 2008, pp. 3–4). As one of the examples in which each tissue becomes uniform and cooperative to exhibit its emotion, neural cells synchronize one after another as nervous tissue through the sequent depolarization over the threshold of each neuron to transmit the one-way electric signals of action potentials in neural organs. Therefore, it is understood that nervous tissue sustains the load of resistant threshold to be overcome by the charged electric energy into each neighboring neuron for the generation of action potential.

The organ of muscle has little difference both from the tissue of muscle and from the cell of muscle because a muscle organ is occupied by its long muscle tissues and a muscle tissue is occupied by its long muscle cells (Marieb et al., 2008, pp. 243, 246). And the contraction of muscle is explained by the sliding mechanism between myosin and actin filaments in a muscle cell such that these long protein filaments slide past one another for the shortening of a muscle organ. The protein of myosin contains the enzyme of ATPase (Pollard and Earnshaw, 2008, pp. 657, 659, 714–715). The myosin head of its filament binds and hydrolyzes ATP, interacting with actin in order to slide along the actin filament. The energy, which is derived from ATP hydrolysis to be stored in the elastic part of the myosin head as conformational change like a kind of stretched spring, is used to displace the myosin head to the next place on the interacting actin filament for the contraction of muscle. In contrast, the energy stored in the stretched myosin is dissipated as heat when the stretch does not overcome the threshold for mechanical work and then these filaments cannot slide. Therefore, it is understood that a muscle tissue and organ are simultaneously extended to sustain the load of stretched tension with thermal energy in order to overcome the resistant threshold for mechanical work. Hence, it is suspected that there is emotion with load and energy for behavior in a tissue or an organ.

One organ connects with the other organs by their common purpose to organize the organ system such as the nervous organ system composed of the brain, spinal cord, motor nerve, sympathetic nerve, etc (Marieb et al., 2008, pp. 4–5). It is proposed that each organ system is further categorized into four collective organ systems — 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, the immune organ system, endocrine organ system, and autonomic nervous system are left by categorically subtracting those four collective organ systems from all organs. Then these residual three systems may be systematized into another collective organ system because they have similar bases, that is, first, they are mainly originated in neural crest and branchial arch; second, they apply the basal levels of materials like cells, proteins, and electrons in comparison with compound tissues, foods, or blood; third, they work under the hypothalamus that is the highest center for immunological fever or endocrine and autonomic nervous functions; fourthly, they are separated from subcortical conditioned reflex and cortical integrated network; fifthly, they utilize the original signals of cytokines, hormones, and neurotransmitters for each regulation; sixthly, they cooperate with each other to regulate all cells, tissues, and organs involving themselves; seventhly, they set the derivative regulation for predatory behavior in addition to the basal regulation for vegetative metabolism or circulation; eighthly, they regulate every homeostatic system with microscopic feedback mechanisms in order to maintain the macroscopic organism (Ganong, 2005, pp. 142, 234, 251, 253–254, 279, 372, 374–375, 460–461, 472, 521–522; Marieb et al., 2008, pp. 392, 406, 460–461, 472, 474; Sadler, 2012, pp. 67, 69, 262, 267).

As a result, immune, endocrine, and autonomic nervous systems can be regarded as one of the collective organ systems, called the regulatory organ system because each organ in the nervous organ system is separately classified either into the denotative collective organ system or the regulatory organ system. Many autonomic reflexes are unified by the hypothalamus where the various activities of visceral organs including body temperature, endocrine function, autonomic nervous function, and emotional response are regulated (Ganong, 2005, p. 232; Marieb et al., 2008, p. 392). Therefore, it is thought that these regulative functions are charged to the regulatory organ system, relating to the formation of emotion at the deeper level of a mind — where the mind seems to have been intuitively expressed as heartful — under the hypothalamus, that is, immunological signals cause irritating inflammation with local heat and systemic fever above the normal temperature against infection from foreign microorganisms; and also, endocrinal signals that always activate the metabolism of all organs accelerate the adrenergic supplies of oxygen and glucose over the ordinary volume of hormonal secretion at alert conditions; and further, neuronal signals switch from comfort in rest to uncomfortable tension beyond the alternative threshold between the sympathetic and parasympathetic nervous systems in emergent situations. Hence, the regulatory organ system has the emotion of tension in unadjusted organs with multicellular excitation such as inflammatory heat, first-aid calorie, or adrenergic voltage for behavior.

The limbic system is the most basal part of the cerebral cortex on the brainstem and contains the amygdala, hippocampus, and cingulate gyrus to be concerned with memory and emotion, including their fibers that link them together in order to form closed neuronal circuits (Ganong, 2005, pp. 256, 258; Marieb et al., 2008, pp. 399, 406). The limbic system, which is the oldest part of the cerebral cortex, has three histological layers in comparison with the neocortex with six histological layers, though the limbic system of a human being is the same structure as with other mammals. Since the limbic system connects the primary cortex that directly receives olfactory signals, this explains why smells often trigger emotion, while the system interacts extensively with the prefrontal cortex, then emotion mediated by the system interacts closely with thought mediated by the thinking brain. However, the connection between the limbic system and neocortex is relatively poor to form a kind of threshold against the latter rational suppression, so that neocortical activity does not modify emotional behavior; and instead of this upward relation, many outputs from the limbic system are sent downward to the hypothalamus and reticular formation for the control of visceral responses, so that the reason why the person under emotional stress experiences visceral symptoms like heartburn or high blood pressure through adrenal medulla and sympathetic nerve is explained.

The cingulate gyrus allows people to shift between thoughts to express emotion through gestures, while the anterior part of the cingulate gyrus interprets pain as unpleasant and resolves mental conflict during frustrating tasks (Marieb et al., 2008, pp. 392, 406). The hippocampus receives cortical data including emotion to process the data in order to be remembered by the rest of the central cortex where data are stored as long term memories. The amygdala forms the memories of experience especially related to fear and also retrieves the memories to cause people to re-experience the original emotion in order to make people decide the effective way of handling difficult situations beforehand. And in fact, fear reaction can be produced in conscious animals by the stimulation of the amygdala, while fear reaction and its endocrine and autonomic nervous manifestations through the hypothalamus are absent after the destruction of the amygdala (Ganong, 2005, pp. 256, 259–262). Meanwhile, the regions concerning the stimulation that leads to reward in rat brain are located in the dopaminergic pathway extending from ventral tegmentum in the midbrain to nucleus accumbens at the base of the striatum. Conversely, the regions concerning the stimulation that is avoided are located in the posterior hypothalamus and dorsal midbrain (Ganong, pp. 260, 263, 268). Thus, the subcortical brain distinguishes pleasant demands like appetite or sexuality from unpleasant pressures like fear or conflict to behave alternatively.

Hence, it is thought that the subcortical brain excites its instinct either with pleasantness or frustration as the emotion of oppression in order to efficiently behave with limited liberty in diverse nature with high degree of freedom.

Olfactory nerves are ultimately relayed to the primary olfactory cortex to result in conscious awareness of more than 10,000 different odors in human beings (Ganong, 2005, pp. 186, 189; Marieb et al., 2008, pp. 396, 399). The gustatory cortex is related to the conscious awareness of taste and the discrimination of sweet, salt, sour, bitter, and umami, while the visceral sensory cortex receives the general sensory input of pain, pressure, or hunger from thoracic and abdominal organs. Stimulation to the feeding center of the medial forebrain in conscious animals evokes the appetite for food. Further, the limbic association area that is located on the medial side of frontal lobe processes emotions involved in complex personal and social interaction to guide emotional response, and also the limbic association area aids in the formation of memory and uses this past experience to integrate sensory and motor inputs with the memory in the lobe for future behavior (Marieb et al., 2008, pp. 400–401). The right hemisphere of cerebral cortex is more concerned with emotion or artistic and musical skills though the left hemisphere has greater control over logic or math with certain thresholds between them in most people (90% to 95%). Then the corresponding region in the right hemisphere to Broca's area, which receives the inputs of meanings and concepts from recognition to form the outputs of words toward the premotor cortex for speech, controls emotional overtones given to spoken words. Therefore, it is understood that the cortical brain feels more differentiated satisfaction and complaint as innumerable emotion according to the category of meaning and concept in conscious recognition and logic. And it is thought that consciousness develops motive as the emotion of subjective and objective feelings, where the world of consciousness is more widened and deepened in order to live existentially in complex society.

Subcortical emotion in the limbic system is separated from cortical emotion in the neocortex, though the limbic system and neocortex are more or less connected. It is thought that subcortical emotion is intuitively recognized as a subconscious subject in itself while cortical emotion is objectively represented as a conscious subject through the thresholds of social concept and logic. And the number of patterns in subcortical emotion is few in comparison with cortical emotion, as well as the number of patterns in subcortical logic and behavior is incomparably less than the number of directions in the vectors of cortical ones. In addition, it is conjectured that the subcortical brain has the emotion of oppression that always wants to be efficiently superior to the predatory rivals, whereas the cortical brain has the emotion of feeling that often tries to be diversely tolerant to social others.

Stress in biology has been defined as any pressure in the system that changes or threatens to change an existing steady state (Ganong, 2005, p. 370). If a homeostatic system is attacked by any pressure to counteract the stress with emotion, this emotion can lead the system to restore the changed state back to the original state. There are some phases in emotion, i.e., the conative surge to take action, the physical symptom like blush or tremble, the affective demand of instinct, and the cognitive awareness of sensation (Ganong, 2005, p. 256). From this viewpoint, it is thought that emotions in a cell, the regulatory organ system, the subcortical brain, and the cortical brain are respectively consistent with conative surge, physical symptom, instinctive affect, and objective sensation because each emotion is related to a charged response with threshold, adrenergic reaction with heat, predatory behavior with sex, and social conduct with consciousness. Originally, each system in these differentiated levels respectively shoulders the pressure of biological disorder, regulatory imbalance, subconscious conflict, and conscious irrationality. Then it is suspected that these systems prepare transmembrane barrier with ATP in a cell, inter-organ disproportion with excitation in the regulatory organ system, predatory frustration with excitement in the subcortical brain, and social complaint with the right hemispherical motive in the cortical brain to counteract their troubles directly without logical thinking for emotional behaviors. And as the structure of logic, these systems construct correspondent feedback in a cell, reflective feedback in the regulatory organ system, conditioned reflex in the subcortical brain, and integrated network in the cortical brain to solve their problems through indirect feedback logic. Hence, it is concluded that the structure of emotion has appeared in each homeostatic or differentiated system as cellular load with resistance and potential, as regulatory tension with discomfort and comfort, as subconscious oppression with frustration and pleasantness, and as conscious feelings with complaint and satisfaction in order to respectively transcend cellular disturbance, multicellular disharmony, predatory insufficiency, and social inconsistency by means of another dimension against logic to behavior.

A living thing succeeds its life from generation to generation using both the genetic materials such as nucleic acid or phosphoric acid and the enzymatic machineries such as DNA polymerase or RNA polymerase (Watson et al., 2008, pp. 132, 257). An organism survives only if its DNA is replicated accurately both through favorably geometric alignment between two pairs of nucleotides and through correspondently complementary relationship between nucleotide and polymerase to give DNA its self-coding character (Watson et al., 2008, pp. 106, 198–199, 204–205). Then high rates of mutation in the soma cell would destroy the individual, and high rates of mutation in the germ cell would destroy the species (Watson et al., 2008, p. 257). Nevertheless, if the genetic materials were perpetuated with perfect fidelity, the genetic variation needed to drive evolution would be lacking and then new species would not have arisen. Thus, it is understood that a life depends on a happy balance between the efficiency of exact replication and the diversity of rare mutation. A major limit to the accuracy of replication comes from tautomerization, where there are two isomeric states of tautomeric nucleic acids that are in the relation of equilibrium and also have the different predominance for the pairing of nucleic acids, because the occasional flickering of low-predominant pairing that allows the incorrect pairing of nucleic acids for mutation rarely occurs (Watson et al., 2008, pp. 105, 208, 257). Therefore, it is thought that the flickering between high and low dominant tautomeric nucleic acids in equilibrium is correspondent to the emotion by which a gene overcomes the gradient of dominance between isomeric nucleic acids for the chance of evolution. It seems as if the river of emotion has been traced downstream from the accident of alternative difference with fluctuation, which may be the origin of emotion, in a gene, through the load of transmembrane resistance with energy in a cell, and then through the tension of multicellular unbalance with excitation in the subconscious regulatory mind, and further through the oppression of predatory conflict with excitement in the subconscious instinctive mind, to the feelings of social friction with the right hemispherical motive in conscious mind.

References

Ganong, W.F. (2005). *Review of medical physiology.* San Francisco: McGraw Hill.
Kumar, V., Abbas, A.K., Fausto, N., and Aster, J. (2010). *Pathologic basis of disease.* Philadelphia: Elsevier.
Marieb, E.N., Mallat, J., and Wilhelm, P.B. (2008). *Human anatomy.* San Francisco: Pearson Education.
Nelson, D.L., and Cox, M.M. (2008). *Principles of biochemistry.* New York: W.H. Freeman and Company.
Pollard, T.D., and Earnshaw, W.C. (2008). *Cell biology.* Philadelphia: Elsevier.
Sadler, T.W. (2012). *Langman's medical embryology.* Philadelphia: Lippncott Williams and Wilkins.
Watson, J.D., Baker, T.A., Bell, S.P., Gann, A., Levin, M., and Losick, R. (2008). *Molecular biology of the gene.* New York: Pearson Education.