Is there anything “autonomous” in the nervous system?

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Rasia-Filho, Alberto A. Is there anything “autonomous” in the nervous system? 

Adv Physiol Educ 30: 9–12, 2006; doi:10.1152/advan.00022.2005.—The terms “autonomous” or “vegetative” are currently used to identify one part of the nervous system composed of sympathetic, parasympathetic, and gastrointestinal divisions. However, the concepts that are under the literal meaning of these words can lead to misconceptions about the actual nervous organization. Some clear-cut examples indicate that no element shows “autonomy” in an integrated body. Nor are they solely “passive” or generated “without mental elaboration.” In addition, to be “not consciously controlled” is not a unique attribute of these components. Another term that could be proposed is “homeostatic nervous system” for providing conditions to the execution of behaviors and maintenance of the internal milieu within normal ranges. But, not all homeostatic conditions are under the direct influence of these groups of neurons, and some situations clearly impose different ranges for some variables that are adaptative (or hazardous) in the tentative of successfully coping with challenging situations. Finally, the name “nervous system for visceral control” emerges as another possibility. Unfortunately, it is not only “viscera” that represent end targets for this specific innervation. Therefore, it is commented that no quite adequate term for the sympathetic, parasympathetic, and gastrointestinal divisions has already been coined. The basic condition for a new term is that it should clearly imply the whole integrated and collaborative functions that the components have in an indivisible organism, including the neuroendocrine, immunological, and respiratory systems. Until that, we can call these parts simply by their own names and avoid terms that are more “convenient” than appropriate.

sympathetic; parasympathetic; vegetative; homeostasis; visceral

THE TERMS “autonomous” or “autonomic” are commonly used to identify one part of the nervous system that deals with adjustments of widespread physiological variables needed for maintenance of life and occurrence of behaviors. The so-called “autonomic nervous system” (ANS) has been divided in two broad parts: sympathetic and parasympathetic. In addition, a third component has been included and is called the “enteric” nervous system, which differs in structure and function from the two foregoing divisions (2).

The definition found in dictionaries for autonomic refers to something that has autonomy, self-government. Autonomy, by its turn, is something that is independent (7, 25). However, there is nothing in our whole indivisible body that is literally independent, that works without being affected by any other system or that can decide, by individual “desire,” when to execute (or not) a given function. If so, imagine what a coincidence it must be to behave as we normally do if all parts of our organism were embodied with own “free will.” As stated, “The autonomy of this part of the nervous system is illusory, since it is intimately responsive to changes in somatic activities” (2). All body systems are dependent and affected by the action of others in a multicellular organization. And this dynamic relation is in the core of homeostasis, a fundamental concept in physiology (4–6). Unfortunately, the term autonomic itself should not be even considered didatic, and, although it might be considered a “subtle” incorrectness and a historical contribution, it is actually a conceptual mistake about nervous organization (3).

When thinking of another nomenclature to be employed, the second term usually used to describe the sympathetic, parasympathetic, and gastrointestinal tract neural components is “vegetative.” For example, “vegetative nervous system,” “neurovegetative,” or “vegetative responses” are sometimes employed instead of ANS or autonomic responses. Notwithstanding, when looking for the meaning of vegetative, one is addressed to something that is “involuntary or passive” (“like the growth of plants”) or “showing little mental activity.” Involuntary is something that is “not done of one’s own free will, unintentional, accidental, not consciously controlled, automatic” (7, 25). Let us consider this definition further. The effects of these neurons are not unintentional or passive or involving little “mental” activity. And these terms are not synonymous and do not imply the same as “not consciously controlled” or “unconscious.” In sharp contrast with this definition, neural activities are intentionally activated for the adequacy of the physiological variables according to the ongoing needs of the behaving animal. They are not merely

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passive ones or “side effects;” rather, they should represent the best (or, sometimes, the possible) combination for the organic variables at each moment. These homeostatic adjustments (with the afferent and efferent pathways they involve) are purposeful and organized concomitantly with behaviors to provide basic conditions for their executions, including those ones with no apparent somatic motor activity modifications (3, 23).

In addition, consciousness would not to be an epiphennomenon of neuralgial processing of information. Rather, it appears to be an activity needed for data interpretation and for choice decisions (24), although it is very likely that most of nervous system function occurs without conscious awareness. If “not consciously controlled” was considered as a need for being considered vegetative, the neurochemical control of body weight, basal ganglia implicit memories (10), and the perception of backwardly masked fearful faces by the amygdala (9) should also be included in this same category (and they never were indeed). Also, involuntary and clearly related with motor acts are the spinal organization of the stretch reflex, the proprioceptive afference to the cerebellum, or the active inhibition of most skeletal muscles when dreaming occurs (10). This would serve to comment that the activity of sympathetic, parasympathetic, and gastrointestinal divisions could not be stated as the “involuntary motor system” as a proper, unique, or ultimate characteristic of them. Furthermore, there is no “motor” activity in the relevant sympathetic innervation of the kidney, adrenal medulla, and so on.

It is beyond doubt that some physiological variables are not under complete voluntary control. For example, it could be said that no one is able to greatly decrease one’s own heart rate and blood pressure. This does not necessarily mean that volition cannot affect them, because “biofeedback” training can provide useful adjunct results for the treatment of moderate essential hypertension (26). Also well known are the changes in cardiovascular variables related to voluntary motor acts or associated with emotionally loaded situations, when these changes are intended to help the animal better cope with the situations. In this same regard, in the treatment for precocious ejaculation or in some cases of male impotence, “mental” activity has to occur for emission controlling or for conscious awareness of the suspected “psychological” [that is “organic,” by definition, because is happening in a body organ (19)] cause of the dysfunction.

Therefore, let us see if another, better term can emerge from functional evidences based on classical responses displayed by the sympathetic and parasympathetic nervous systems. It is not unusual to hear or read or sometimes it stays implicit that actions of these divisions promote opposite effects in the organs they innervate. However, for the precise aim of a homeostatic response that requires effectiveness, energy economy and sometimes fast responses, the sympathetic and parasympathetic can be adjoined and collaborate for a final net effect. The mobilization of physiological variables does not occur in an all-or-none manner and is not exclusive of extreme “fight or flight” conditions; rather, they can occur with graded intensities in ordinarily daily situations (23). For instance, if one needs to enhance blood pressure, a higher gain in the response can be obtained with concomitant enhancement of sympathetic activity and inhibition of parasympathetic activity. This is obtained not only in the central nervous system areas that control blood pressure but also by reciprocal inhibitory innervations in the heart wall (1, 15, 17, 22). “Both divisions are tonically active and operate in conjunction with each other and with somatic motor system to regulate most behavior, be it normal or emergency. Although several visceral functions are controlled predominantly by one or other division . . . it is the balance of activity between the two that helps maintain an internal stable environment in the face of changing external conditions.” (14)

Indeed, these counteractions have to be emphasized because it would be puzzling to find the general purpose for some physiological variables changes when they are studied isolated. Integrated, in the context of the need of an adequate behavior, they are logically linked. An animal that is faced with a threatening situation has to decide, among different strategies, what is apparently the best choice for the conservation of its life and, in a broad sense, of its species. For example, when sympathetic activation occurs, cardiac output and systemic blood flow increase and, whereas vasodilation occurs for increasing the blood supply to active skeletal muscles for posture and intended movements, vasoconstriction in the skin can reduce blood loss in a region that is highly susceptible of damage. A decreased time for blood clothing avoids a great hemorrhage, and a higher sudoresis makes the skin moistened and the animal difficult to be caught. At the same time, there is enhanced breathing movements and airflow volume for gaseous changes and pH regulation. Liver glycogenolysis is stimulated, along with the mobilization of fatty acids from adipose tissue. Muscular strength and muscle glycolysis are also improved and, for additional energy production, also occur with higher oxygen-hemoglobin dissociation and oxygen delivery to activated cells. Wave frequencies in the EEG increase, which reflects diffuse neuronal activation, and mydriasis serves to have more visual information and for deciding the best behavioral strategy to execute, such as skipping out of a dangerous place. By the action of α-adrenergic receptors, the secretion of insulin is inhibited (it would be useless to restore energy reserves at this moment) and glucagon secretion is stimulated by β-adrenergic receptors. Cortisol, as well as other stress-related hormones, can be more released into the circulation, and adrenal hormones can indirectly affect the consolidation of memories. Cells of the immunological system, lymphoid tissues, and cytokines are also involved in this integrated response.

On the basis of these data and because these responses, including the metabolic ones, can no longer be claimed literally as autonomic or vegetative, it could be proposed a name of nervous system for “homeostatic regulation.” This term would incorporate the sympathetic, parasympathetic, and gastrointestinal divisions and correctly put together the cardiovascular, respiratory (and its motor component for breathing), renal, endocrine (with its neuroendocrine control), and hematological systems for a common physiological purpose. “Our studies of bodily homeostasis can then take place in a wider context. Thus, in a study of fluid and electrolyte balance, observations of behavioral strategies used to find water and salt in deficient environments will take their place along with relevant hormonal and neural control of absorption and excretory mechanisms” (3). Moreover, dynamic fluctuations in the normal range of functioning of this “homeostatic nervous system” are quite possible, actively elaborated, and actually expected to
occur. Ample and physiological variations can be found in some parameters along time (e.g., those described as circadian rhythms) or in certain sleep phases, after eating sustaining food, or even in the early days of babyhood. Being repetitive and under normal situations, a healthy body should bear the brunt of them safely during certain periods of time. Obviously, some events can be out of control and lead to serious health hazards; but, should these changes always be harmful to an animal whenever it is faced with a new situation, probably then ours and other species would not be here. Cannon (4), in his book The Wisdom of the Body, addressed this topic: “In 1907, Metzer, in an important and suggestive paper, drew attention to a group of facts which he had gathered to throw light on the question whether our bodies are organized on a generous or on a narrowly limited plan. He pointed out that when an engineer estimates the weights which a bridge or beam must support, or the pressures to which a boiler will be subjected, he does not provide merely for those stresses in building the structure. The engineer multiplies his estimates by three, six or even by twenty, in order to make the structure thoroughly reliable. The greater strength of the material, above that calculated as necessary, measures what is known as a “factor of safety.”

Nevertheless, it could be argued that not all homeostatic conditions are under the strict control of the sympathetic, parasympathetic, or gastrointestinal nervous system. For example, homeostatic control also includes the regulation of plasmatic electrolytic, pH, and gaseous composition. Although there are relevant sympathetic afferences to the kidneys (8), the ultimate maintenance of homeostatic levels of Na⁺ and K⁺ in the circulation is not directly or solely an effect mediated by renal catecholamines. An animal with destruction of the sympathetic nervous system is unable to normally respond to variations of hidric and electrolytic balance (13). However, this division is not essential to life when the animal is living in a controlled environment because, fundamentally, each different tissue possesses the ability to autoregulate local blood flow to ensure normal short-term and long-term functioning based on metabolic and functional needs (11). Likewise, some behaviors can be programmed and executed to correct or maintain variables within normal ranges. But, for the proper execution of some behaviors or due to them, some reflex responses can be “bypassed,” and homeostatic adjustments found in resting can become intentionally inhibited or temporarily adjusted by hierarchal reasons of importance. That is, exercise or defense reactions are accompanied by a programmed decrease of the baroreceptor reflex–related cardiovascular response, increased breathing amplitude can occur in awake and behaving animals due to the inhibition of the Hering-Breuer inflation reflex (23), thermoregulatory responses to environmental thermal loads are suppressed during paradoxal sleep (18), and thirst ceases immediately after an animal drinks water, several minutes before blood osmolarity is restored to a lower value (23).

Animals might also have to achieve stability of their variables through changes of state related to challenging circumstances. In this sense, the concept of “allostasis” (allo, meaning different, and stasis, meaning constancy, i.e., “achieving stability through change”) was introduced to take into account regulatory systems that develop variable set points of control, show individual differences in expression according with the capacity of the animal to cope with new situations, are associated with anticipatory behavioral and physiological responses, and are vulnerable to physiological overload and the breakdown of regulatory capacities (16, 20). It is the viability of the internal milieu that is aimed toward when the needs exceed the limiting capacity of the system. They can lead to acute adaptations or to chronic situations and can have damaging side effects by imposing the establishment of different ranges for some variables, as in the endocrine and immunological systems (21) or in obesity-related hypertension (12). On the other hand, these adaptations would represent that “control systems must be capable of radically reorganizing themselves in response to long-term changes in circumstances . . . called ultrastability, the ability to maintain homeostasis not by local hill climbing, small incremental changes in the model’s parameters, but by a sort of leap to a neighboring peak.” (for details, see Ref. 5).

Finally, taking into account the end targets that are under control, another term for the sympathetic, parasympathetic, and gastrointestinal divisions could be suggested: “nervous system for visceral control.” Accordingly, the sympathetic and parasympathetic systems innervate and form the “visceral (splanchnic) component of the nervous system” (2). It has already been stated that “the autonomic nervous system is a visceral sensory and motor system” . . . and . . . “visceral reflexes are not under voluntary control, nor they impinge on consciousness, with few exceptions” (14). From the above-mentioned statements, let us remember that unconscious is not necessarily the same as autonomic. And, whereas viscera means the “large internal organs of the body,” it does not represent unique end targets for this innervation. It is right that these nerves are found reaching and close to viscera, but it is also true that they can be found in salivary glands, blood vessels, smooth muscle, adipocytes, mast cells, melanophores, interstitial cells, and motor end plates (2, 13).

Regrettably, it was not possible to find a term that quite satisfied the morphological and physiological characteristics of the group of neurons in discussion. It is argued here that the current terms for the sympathetic, parasympathetic, and gastrointestinal components of the nervous system are not completely adequate. Indeed, “what is in a name” and what does it imply? It still deserves further academic debate to coin another term with the formal obligation to include the characteristics of the components it is naming and, in addition, to consider their inseparable and parallel actions in the functional conjuncture of one sole animal body. But, could the solution for this issue be even easier? Maybe one can say yes. Instead of pursuing a name that can be prone to objections, it could be simply left as an intellectual challenge to find words that must congregate heterogeneous structures or that can involuntarily hide some relevant aspects of their anatomic and functional organization, this last possibility would be accepted without great effort. And, most importantly, it shall not serve to perpetuate names that are more “convenient” than appropriate (2), even more when teaching to our students. These students shall also learn the purposes of the integrated actions of cells, tissues, and organs. For the reasons life is based and life is for in dynamic organisms.
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