Higher Function of the Nervous System

The Postural Control System

Postural control is a term used to describe the way our central nervous system (CNS) regulates sensory information from other systems in order to produce adequate motor output to maintain a controlled, upright posture. The visual, vestibular, and somatosensory systems are the main sensory systems involved in postural control and balance.

- Postural orientation and equilibrium are two main functional goals of postural control.
- Postural orientation is the ability to maintain an appropriate relationship between body parts (alignment) and between the body and the environment (using multiple sensory inputs) for the purpose of performing a certain task.
- The coordination of sensorimotor strategies to stabilize the body's center of mass during both self-initiated and externally triggered stimuli constitutes postural equilibrium.
- Postural equilibrium and Postural orientation are different but also can be interdependent, for example patients with camptocormia (involuntary forward flexion of the hips) can have excellent control over their center of mass (postural equilibrium). In contrast, other patients can have excellent postural orientation in terms of alignment and multisensory orientation to the external environment and still be at risk of falling due to poor postural control. They also can be interdependent as studies have shown that a flexed postural orientation of the legs and trunk compromises the ability to recover equilibrium in response to perturbations.

  Proper postural control is when an individual is able to engage in various static and dynamic activities, such as sitting, standing, kneeling, quadruped, crawling, walking, and running with the ability to contract the appropriate muscles required for a controlled midline posture, as well as the ability to make small adjustments in response to changes in position and movement, without the use of compensatory motions.

If even one of the three abovementioned systems is not working the way it is supposed to, it can affect postural control and balance. However, when one system is affected the other two can be trained to compensate. If more than one system is affected in combination with CNS involvement, postural control will be more greatly affected.

There are important reflexes involved in postural control known as the Cervicocollic Reflex (CCR), the Vestibulo-ocular reflex (VOR) and the Vestibulospinal Reflex (VSR) that work in conjunction with the vestibular nuclei and cerebellum (The vestibular system). The visual, vestibular and somatosensory are our three balance systems which are closely linked to control posture.

The vestibular system, somatosensory system and visual system do not act in isolation but are a complex postural control system that work together to achieve balance.

Postural stability happens with good sensorimotor integration between the upper cervical spine, visual and vestibular structures. Poor postural control occurs if there is a sensory mismatch, in other words the CNS is unable to distinguish between accurate and inaccurate sensory information from one or more of these systems, resulting in feelings of dizziness/unsteadiness/poor balance, and disruption in predictive timing of sensory input.

Patients often complain of headaches, dizziness, blurry vision, frontal headaches, eye strain and balance problems, often have difficulty reading (horizontal deficits), they become headachey/dizzy when looking up at the board and down at the desk during note-taking (vertical deficits). These patients can also experience neck pain, as they may have an increase in muscle activity/stiffness as the body tries to compensate for a loss of balance. They can even be symptomatic while running and trying to focus on a target such as a ball. Some patients complain of feeling disoriented/overwhelmed when driving in an unfamiliar city, driving in tunnels or pushing a trolley in the grocery shops.

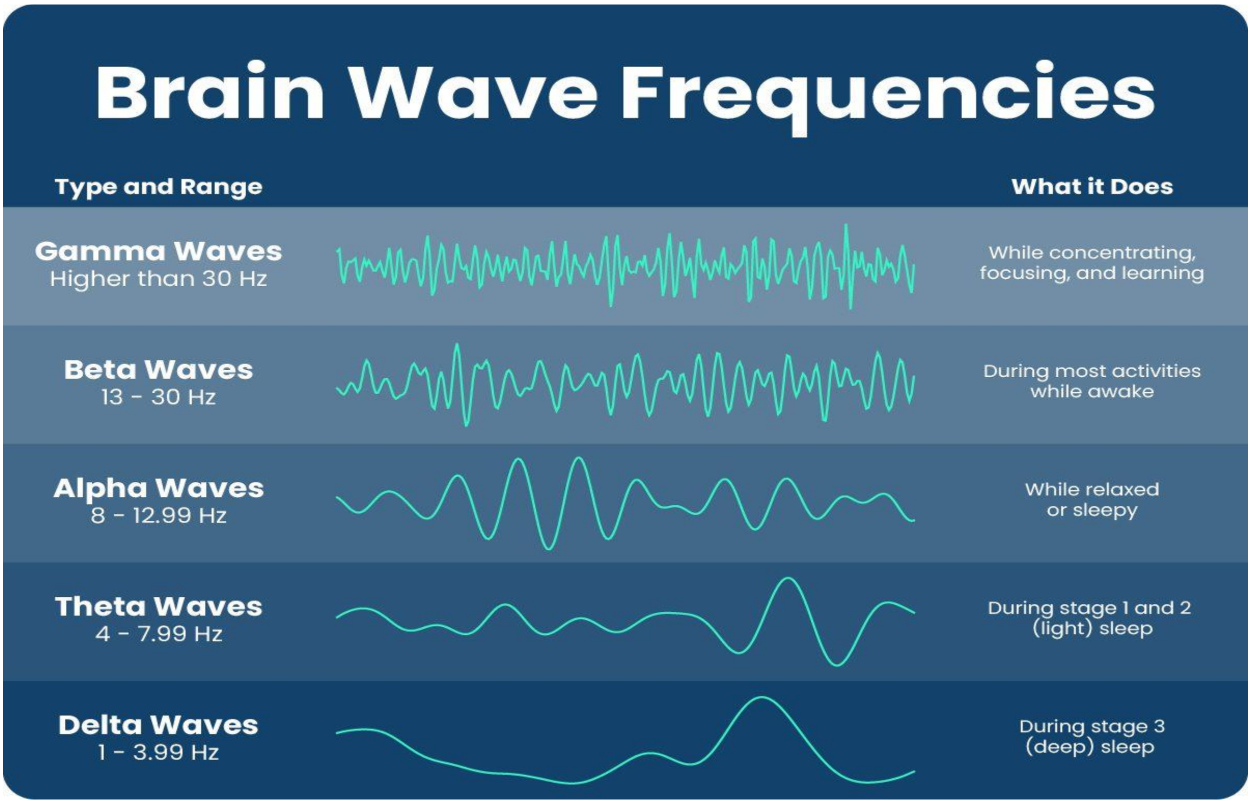
Physiological and Behavioral Aspects of Sleep

Sleep is a biological necessity and studies in animals showed that sustained loss of total sleep or substantial loss of particular sleep stages leads to failure of body temperature regulation, increased metabolism, deterioration of hypothalamic neurons, progressive breakdown of host defenses, and death. These observations support theories that sleep functions to conserve energy and metabolism; keep physiological systems within proper homeostatic limits; maintain host defenses; and reverse or restore physiological processes that get progressively degraded during wakefulness.

Sleep Stages

Sleep is divided into two distinct stages—non–rapid eye movement (NREM) and rapid eye movement (REM) sleep. NREM sleep is divided into three stages (Stages 1, 2, 3). These gradually deepen and are associated with larger and slower brain wave activity.

The staging of sleep is based on brain wave activity (electroencephalography), eye movements (electro-oculography), and muscle tone (electromyography).



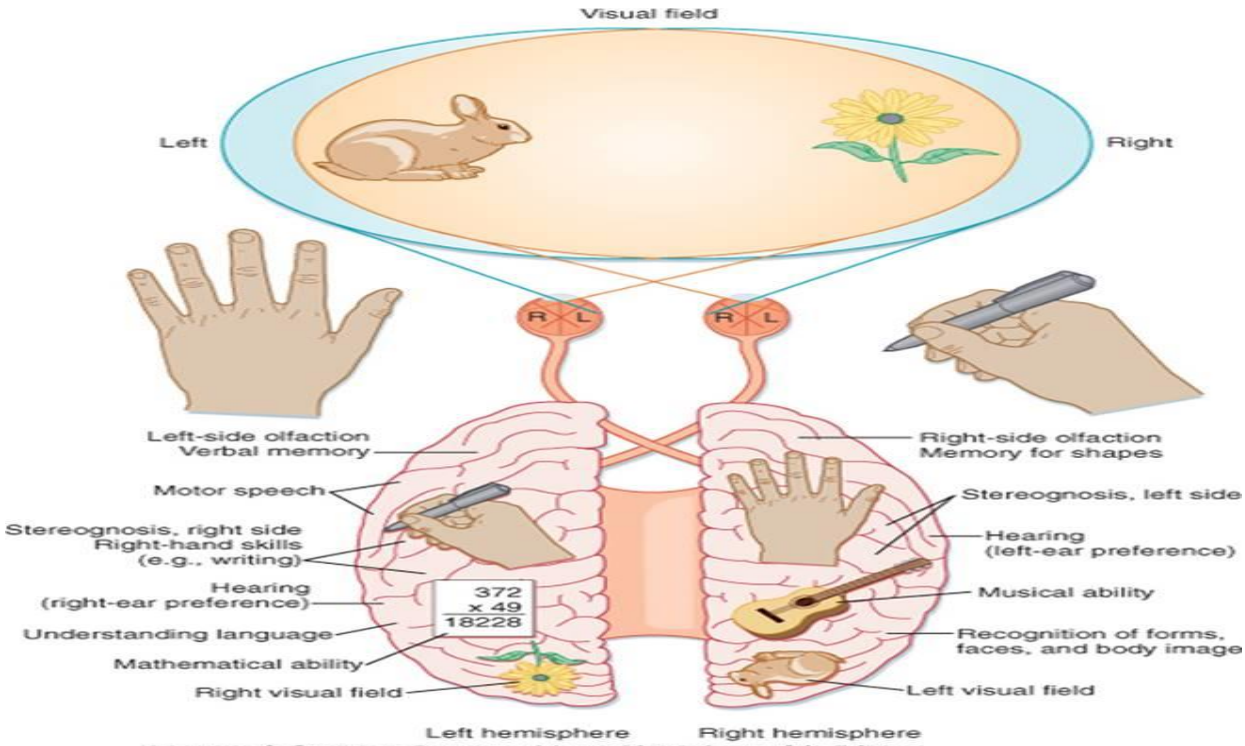
Physiological Changes during NREM and REM Sleep

Physiological Variable	NREM	REM
Brain activity and blood flow	Decreases from wakefulness, especially in cerebral cortex.	Increases from NREM, especially in parts of the cerebral cortex, midbrain, and brainstem core.
Heart rate and blood pressure	Decreases from wakefulness.	Increases and highly variable compared to NREM.
Sympathetic nerve activity	Decreases from wakefulness.	Increases from both NREM and REM in some body areas.
Muscle tone	Slightly lower from wakefulness.	Absent.
Respiration	Decreases from wakefulness, displays rhythmic periodicity in breathing amplitude.	Increases and varies from NREM, may show brief stoppages; coughing suppressed.
Airway resistance	Increases from wakefulness.	Increases and varies from wakefulness and NREM.
Body temperature	Regulated at lower level from wakefulness.	Is not regulated, no shivering or sweating.
Swallowing and gastrointestinal motility	Suppressed from wakefulness.	Suppressed from wakefulness.

The secretion of melatonin rises prior to sleep onset and remains elevated throughout the nocturnal sleep period. Melatonin secretion is controlled by ambient light levels, and the plasma concentration of melatonin rises with onset of darkness. It remains elevated during sleep, even during periods of wakefulness in the dark after sleep onset, but is suppressed by exposure to light.

Cortisol reaches its lowest level (trough) during the early part of the sleep period and reaches its highest level (peak) shortly before or after waking up.

Major functions of the higher levels of the nervous system are learning and memory. Learning is a neural mechanism by which the individual changes behavior as the result of experience. Memory refers to the storage mechanism for what is learned.



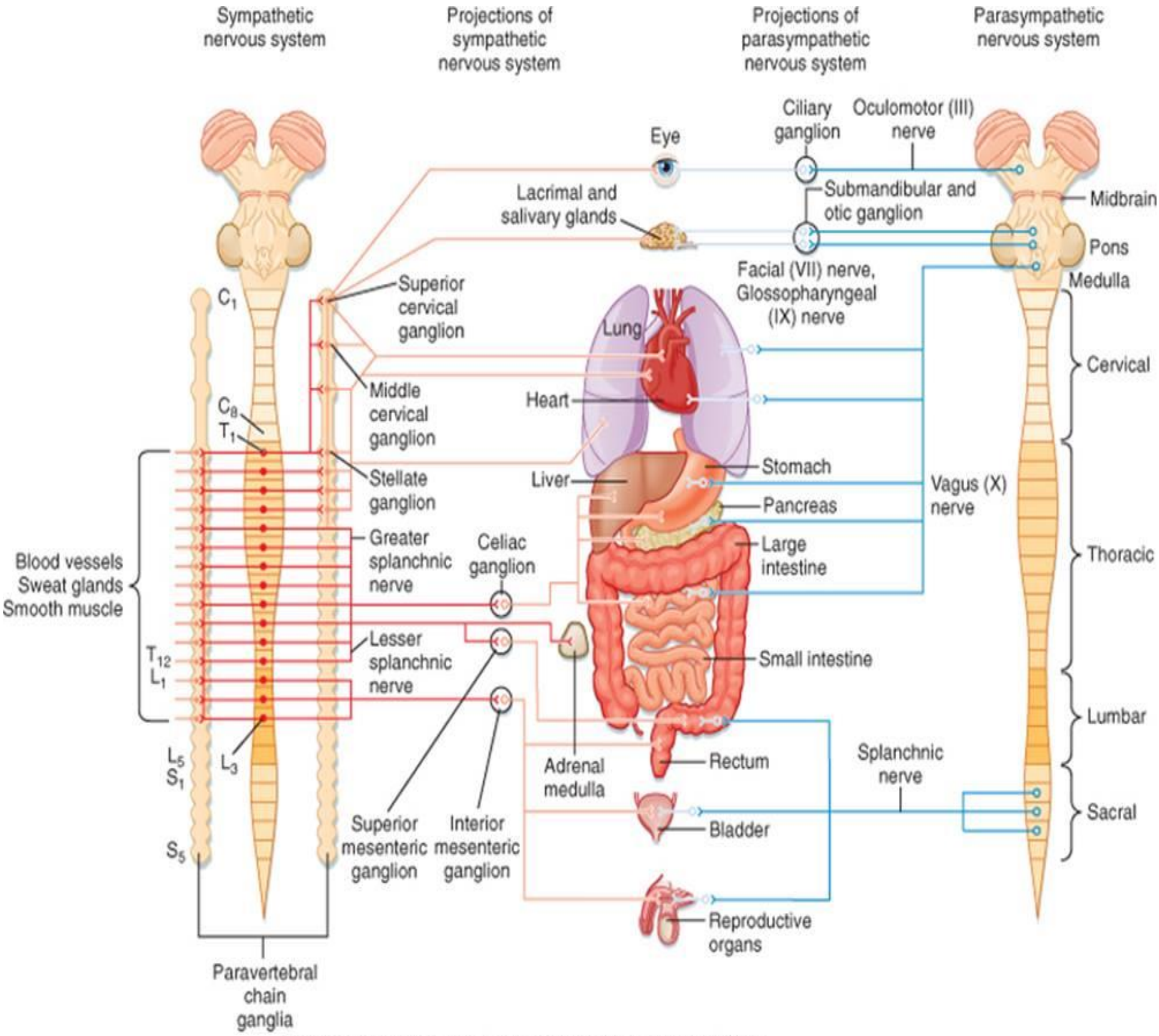
Koeppen & Stanton: Berne and Levy Physiology, 6th Edition.

With regard to the stages of memory storage, a distinction between **short-term memory** and **long-term memory** is useful. Recent events appear to be stored in short-term memory by ongoing neural activity because short-term memory persists for only minutes. Long-term memory can be subdivided into an intermediate form, which can be disrupted, and a long-lasting form, which is difficult to disrupt. The temporal lobes appear to be particularly important for memory. Two areas important for planning and executing motor tasks are the parietal cortex and the frontal cortex, the former because it integrates sensory information needed to define the context of a task and the latter because it has neurons that direct all the components for motor execution.

The Autonomic Nervous System

The **autonomic nervous system** is often regarded as a part of the motor system. However, instead of skeletal muscle, the effectors of the autonomic nervous system are smooth muscle, cardiac muscle, and glands. Because the autonomic nervous system provides motor control of the viscera, it is sometimes called the **visceral motor system.** The autonomic system is a purely motor system; however, autonomic motor fibers in peripheral nerves are accompanied by visceral afferent fibers that originate from sensory receptors in the viscera. Many of these receptors trigger reflexes, but the activity of some receptors evokes sensory experiences such as pain, hunger, thirst, nausea, and a sense of visceral distention. An important function of the autonomic nervous system is to assist the body in maintaining a constant internal environment **(homeostasis).** When internal stimuli signal that regulation of the body's environment is required, the central nervous system (CNS) and its autonomic outflow issue commands that lead to compensatory actions. For example, a sudden increase in systemic blood pressure activates the baroreceptors.

The autonomic nervous system also participates in appropriate and coordinated responses to external stimuli. For example, the autonomic nervous system helps regulate pupil size in response to different intensities of ambient light. An extreme example of this regulation is the "fight-or-flight response" that occurs when a threat intensively activates the sympathetic nervous system. Such activation causes a variety of responses. Adrenal hormones are released, the heart rate and blood pressure increase, bronchioles dilate, intestinal motility and secretion are inhibited, glucose metabolism increases, pupils dilate, hairs become erect because of the action of pilo-erector muscles, cutaneous and splanchnic blood vessels constrict, and blood vessels in skeletal muscle dilate. The primary functional unit of the sympathetic and parasympathetic nervous systems is the two-neuron motor pathway, which consists of a preganglionic neuron, whose cell body is located in the CNS, and a postganglionic neuron, whose cell body is located in one of the autonomic ganglia, The enteric nervous system includes the neurons and nerve fibers in the myenteric and submucosal plexuses, which are located in the wall of the gastrointestinal tract.



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The sympathetic preganglionic neurons are located in the thoracic and upper lumbar segments of the spinal cord. For this reason, the sympathetic nervous system is sometimes referred to as the **thoracolumbar division** of the autonomic nervous system. In contrast, the parasympathetic preganglionic neurons are found in the brainstem and in the sacral spinal cord. Hence, this part of the autonomic nervous system is sometimes called the **craniosacral division.**

The Enteric Nervous System

The enteric nervous system, which is located in the wall of the gastrointestinal tract, contains about 100 million neurons. The enteric nervous system is subdivided into the myenteric plexus, which lies between the longitudinal and circular muscle layers of the gut, and the submucosal plexus, which lies in the submucosa of the gut. The neurons of the myenteric plexus primarily control gastrointestinal motility, whereas those in the submucosal plexus primarily regulate body fluid homeostasis.

CENTRAL CONTROL OF AUTONOMIC FUNCTION

The discharges of autonomic preganglionic neurons are controlled by pathways that synapse on autonomic preganglionic neurons. The pathways that influence autonomic activity include spinal cord and brainstem reflex pathways, as well as descending control systems originating at higher levels of the nervous system, such as the hypothalamus.

Temperature Regulation

Homeothermic animals are those that are able to regulate their body temperature. When the environmental temperature decreases, the body adjusts by reducing heat loss and by increasing heat production. Conversely, when the temperature rises, the body increases its heat loss and reduces heat production.

Information about the external temperature is provided by thermoreceptors in the skin (and probably other organs such as muscle). Internal temperature is monitored by central thermoreceptive neurons in the anterior hypothalamus. The central thermoreceptors monitor the temperature of blood. The system acts as a servomechanism (a control system that uses negative feedback to operate another system) with a set point at the normal body temperature. Error signals, which represent a deviation from the set point, evoke responses that tend to restore body temperature toward the set point. These responses are mediated by the autonomic, somatic, and endocrine systems.

Cooling causes shivering, which consists of asynchronous muscle contractions that increase heat production. Increases in thyroid gland activity and in sympathetic neural activity tend to increase heat production metabolically. Heat loss is reduced by piloerection (hair standing) and by cutaneous vasoconstriction. Piloerection is effective in animals with fur but not in humans; in the latter, the result is goose bumps. In addition, the hypothalamus, via its widespread connections to cortical regions, will influence the decision to initiate concurrent somatic behavior, in this case possibly putting a jacket on.

Warming the body causes changes in the opposite direction. The activity of the thyroid gland diminishes, which leads to reduced metabolic activity and less heat production. Heat loss is increased by sweating and cutaneous vasodilation.

In fever, the set point for body temperature is elevated. This can be caused by the release of a **pyrogen** by microorganisms. The pyrogen changes the set point, thereby leading to increased heat production by shivering and to heat conservation by cutaneous vasoconstriction.