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Biology

International Advanced Level
UNIT 5: Respiration, Internal Environment, Coordination and Gene Technology

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Anatomy, Autonomic Nervous System

1. The autonomic nervous system is a component of the peripheral nervous system that regulates involuntary physiologic processes including heart rate, blood pressure, respiration, digestion, and sexual arousal. It contains three anatomically distinct divisions: sympathetic, parasympathetic and enteric.

2. The sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS) contain both afferent and efferent fibers that provide sensory input and motor output, respectively, to the central nervous system (CNS). Generally, the SNS and PNS motor pathways consist of a two neurone series: a preganglionic neuron with a cell body in the CNS and a postganglionic neuron with a cell body in the periphery that innervates target tissues. The enteric nervous system (ENS) is an extensive, web-like structure that is capable of function independent of the remainder of the nervous system. It contains over 100 million neurons of over 15 morphologies, greater than the sum of all other peripheral ganglia, and is chiefly responsible for the regulation of digestive processes.

3. Activation of the SNS leads to a state of overall elevated activity and attention: the "fight or flight" response. In this process, blood pressure and heart rate increase, glycogenolysis ensues, gastrointestinal peristalsis ceases. The SNS innervates nearly every living tissue in the body. The PNS promotes the "rest and digest" processes; heart rate and blood pressure lower, gastrointestinal peristalsis/digestion restarts. The PNS innervates only the head, viscera and external genitalia, notably vacant in much of the musculoskeletal system and skin, making it significantly smaller than the SNS. The ENS is composed of reflex pathways that control the digestive functions of muscle contraction/relaxation, secretion/absorption, and blood flow.

4. Presynaptic neurons of both the SNS and PNS utilize acetylcholine (ACh) as their neurotransmitter. Postsynaptic sympathetic neurons generally produce norepinephrine (NE) as their effector transmitter to act upon target tissues, while postsynaptic parasympathetic neurons use ACh throughout. Enteric neurons have been known to use several major neurotransmitters such as ACh, nitrous oxide and serotonin, to name a few.

Sympathetic Nervous System

5. As stated, the SNS enables the body to handle stressors via the "fight or flight" response. This reaction primarily regulates blood vessels. Vessels are tonically innervated, and in most cases, an increase in sympathetic signals leads to vasoconstriction and the opposite with vasodilation. The exceptions include coronary vessels and those that supply the skeletal muscles and external genitalia, for which the opposite reaction occurs. Sympathetic activation increases heart rate and contractile force, which, however, increases metabolic demand and is thus detrimental to cardiac function in compromised individuals.

6. The SNS is constantly active, even in non-stressful situations. In addition to the aforementioned tonic stimulation of blood vessels, the SNS is active during the normal respiratory cycle. Sympathetic activation complements the PNS by acting during inspiration to dilate the airways allowing for an appropriate inflow of air.

7. Additionally, the SNS regulates immunity through innervation of immune organs such as the spleen, thymus, and lymph nodes. This influence may up- or down-regulate inflammation.

Parasympathetic Nervous System

8. As mentioned in the introduction, the vagus nerve is responsible for the "rest and digest" processes. The vagus nerve promotes cardiac relaxation in several aspects of function. It decreases contractility in the atria and less so in the ventricles. Primarily, it reduces conduction speed through the atrioventricular node. Parasympathetic fibers to the head promote salivation, while those that synapse onto the ENS lead to increased peristaltic and secretory activity. The vagus nerve also has a significant effect on the respiratory cycle. In a nonpathological state, parasympathetic nerves fire during expiration, contracting and stiffening airways to prevent collapse. This function has implicated the PNS in the onset of postoperative acute respiratory distress syndrome.

9. Due to the expansive nature of the vagus nerve, it has been described as an ideal "early warning system" for foreign invaders as well as for monitoring the body's recovery. Up to 80% of vagal fibers are sensory and innervate nearly all major organs. Parasympathetic ganglia have been found to express receptors for interleukin-1, a key cytokine in the inflammatory immune response. This, in turn, activates the hypothalamic-pituitary-adrenal axis and SNS, leading to the release of glucocorticoids and NE, respectively.

Postural Orthostatic Tachycardia Syndrome (POTS): A Diagnostic Dilemma

POTS is defined as orthostatic intolerance associated with tachycardia exceeding 120 beats per minute or an increase in the heart rate of 30 beats per minute from baseline within 10 minutes of changing the posture from a lying to standing position, in the absence of long-term chronic diseases and medications that affect the autonomic or vascular tone. There is no drop in blood pressure; it may even rise in the upright posture. Patients experience symptoms such as headache, nausea, tremors, sweating, palpitation and near syncope. Symptoms always occur in the upright posture and disappear on lying down. POTS was first described in 1940, and it is considered one of the common conditions in young females. It occurs most commonly between the ages of 12 and 50 years with a male to female ratio of one : five. The underlying pathophysiological mechanism is assumed to be failure of peripheral vascular resistance to increase sufficiently in response to orthostatic stress, and, consequently, venous pooling occurs in the legs resulting in decreased venous return to the heart. This is compensated for by an increase in heart rate and inotropy.

Box 1

Enteric Nervous System

10. The ENS is composed of two ganglionated plexuses: the myenteric and the submucosal. The submucosal plexus governs the movement of water and electrolytes across the intestinal wall, while the myenteric plexus coordinates the contractility of the circular and longitudinal muscles cells of the gut to produce peristalsis.

11. Motility is produced in the ENS through a reflex circuit involving the circular and longitudinal muscles. Nicotinic synapses between interneurons mediate the reflex circuits. When the circuit activates by the presence of a bolus, excitatory neurons in the circular muscle and inhibitory neurons in the longitudinal muscle fire producing a narrow section of bowel proximal to the bolus; this is known as the propulsive segment. Simultaneously, excitatory neurons in the longitudinal muscle and inhibitory neurons in the circular muscle fire producing the "receiving segment" of the bowel in which the bolus will continue. This process repeats with each subsequent section of the bowel.

12. While much of this discussion has focused on the efferent functions of the ANS, the afferent fibers are responsible for numerous reflex activities that regulate everything from heart rate to the immune system. Feedback from the ANS is usually processed at a subconscious level to produce reflex actions in the visceral or somatic portions of the body. The conscious sensation of the viscera is often interpreted as diffuse pain or cramps that may correlate with hunger, fullness, or nausea. These sensations most commonly result from sudden distention/contractions, chemical irritants, or pathological conditions such as ischemia.

13. Most conditions related to the ENS are congenital in origin and present during early childhood. Enteric neurons function to relax intestinal smooth muscle. Their absence leaves the bowel tonically contracted, obstructing the bowel. Presenting complaints often consist of gastroesophageal reflux, dyspeptic syndromes, constipation, chronic abdominal pain, and irritable bowel syndrome. A notable life threatening disorder of the ENS is Hirschsprung disease. This condition is a failure of embryologic ENS cells to colonize the distal bowel. When the ENS is missing (aganglionosis) or maldeveloped, children experience early constipation, vomiting, eventual growth failure, and possible death. Studies have identified six genes in a causal relationship with Hirschsprung disease. Down syndrome is the most common genetic disorder that predisposes an individual to Hirschsprung disease despite the fact that no genes related to ENS development have been identified on chromosome 21.

The enteric nervous system in gastrointestinal disease etiology.

IBD, a collective term used to describe prolonged inflammation of the gastrointestinal tract, primarily include Crohn's disease (CD), which can present throughout the entire gastrointestinal tract (the most common localization being the terminal ileum), and ulcerative colitis (UC), presenting in the mucosal layer of the colon. En masse, affecting 2.5–3 million people in Europe, IBD is univocally identified as an immune pathology and is believed to develop through interactions between environmental, microbial, and immune-mediated factors in a genetically predisposed host.

The fact that distinct immune cell subsets of the gut are equipped to respond to neuron-derived signals by expressing neurotransmitter and neuropeptide receptors and inversely, that enteric neurons can respond to inflammatory signals via, for instance, expression of cytokine receptors, posits the existence of functional ENS-immune interactions in the modulation of intestinal inflammation. Deciphering these neuro-immune units will likely generate important clues on the role of the ENS in IBD.

Box 2

Sources

Anatomy, Autonomic Nervous System
Joshua A. Waxenbaum, Vamsi Reddy, Matthew Varacallo
In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2021 Jan.
PMID: 30969667 Bookshelf ID: NBK539845

Box 1
Postural Orthostatic Tachycardia Syndrome (POTS): A Diagnostic Dilemma
Kamal Soliman; Steve Sturman; Prabodh K Sarkar; Atef Michael
Br J Cardiol. 2010;17(1):36-39.

Box 2
The enteric nervous system in gastrointestinal disease etiology
Amy Marie Holland, Ana Carina Bon-Frauches, Daniel Keszthelyi, Veerle Melotte & Werend Boesmans
Cellular and Molecular Life Sciences volume 78, pages 4713–4733 (2021)