Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Time 1 hour 45 minutes

Paper reference **WBI15/01**

Biology

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

You must have:
Scientific article (enclosed), scientific calculator, ruler, HB pencil

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*
- **Show all your working out** in calculations and **include units** where appropriate.

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- In questions marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

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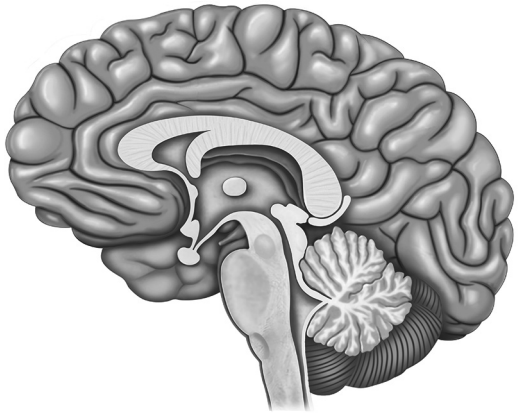
Answer ALL questions. Write your answers in the spaces provided.

Some questions must be answered with a cross in a box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 The brain is made up of more than 1×10^{11} neurones.

(a) The diagram shows a section through the human brain.



(Source: © ilusmedical/Shutterstock)

Label the diagram to show the location of the following:

- pituitary gland
- medulla oblongata
- cerebral hemisphere (cerebrum)

(3)

(b) Complete the table to show the parts of the brain and their functions.

(2)

Part of the brain	Function
cerebellum	
	control of heart rate
cerebral hemisphere (cerebrum)	

(Total for Question 1 = 5 marks)

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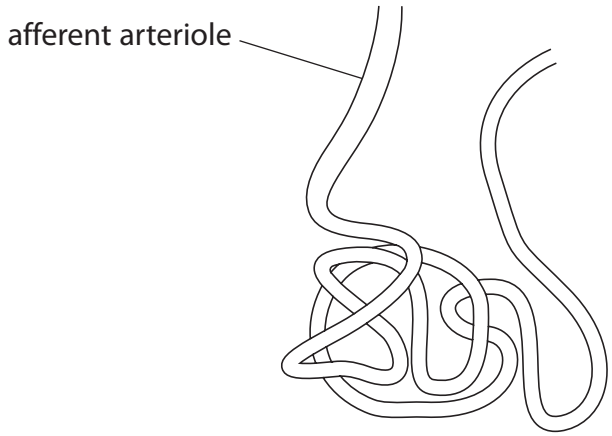
2 The kidney is an organ that is involved in the removal of waste metabolites from the blood.

(a) The drawing shows the blood supply inside a Bowman's capsule (renal capsule).



(i) Complete the diagram to show the Bowman's capsule and label **two** structures in this diagram.

(3)

(ii) Which substances are normally filtered from the blood in the Bowman's capsule?

(1)

☒ **A** amylose and glucose

☒ **B** glucose and sodium chloride

☒ **C** potassium ions and haemoglobin

☒ **D** urea and prothrombin

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(iii) Which row shows the route taken by a water molecule through a nephron in the kidney?

(1)

		Route through a nephron →			
☒	**A**	collecting duct	proximal tubule	distal tubule	loop of Henle
☒	**B**	loop of Henle	proximal tubule	collecting duct	distal tubule
☒	**C**	proximal tubule	distal tubule	loop of Henle	collecting duct
☒	**D**	proximal tubule	loop of Henle	distal tubule	collecting duct

(b) Describe how glucose reabsorption takes place in the nephron.

(3)

(c) Urea is produced by the metabolic breakdown of some organic molecules.

Which statement describes the production of urea?

(1)

☒ **A** in the kidneys from excess amino acids

☒ **B** in the kidneys from glycogen

☒ **C** in the liver from excess amino acids

☒ **D** in the liver from glycogen

(Total for Question 2 = 9 marks)

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3 Chemicals are used to regulate responses in both plants and animals.

(a) In mammals antidiuretic hormone (ADH) is involved in regulating plasma concentration and blood volume.

(i) Which of the following produces ADH?

(1)

- ☒ **A** adrenal gland
- ☒ **B** hypothalamus
- ☒ **C** medulla oblongata
- ☒ **D** pituitary gland

(ii) Which structures does ADH act on?

(1)

- ☒ **A** capillaries
- ☒ **B** collecting ducts
- ☒ **C** proximal tubules
- ☒ **D** ureters

(iii) The control of plasma concentration and blood volume in the body is an example of which type of process?

(1)

- ☒ **A** countercurrent multiplier
- ☒ **B** habituation
- ☒ **C** negative feedback
- ☒ **D** positive feedback

(iv) Name the type of receptor in the body that detects changes in the plasma concentration.

(1)

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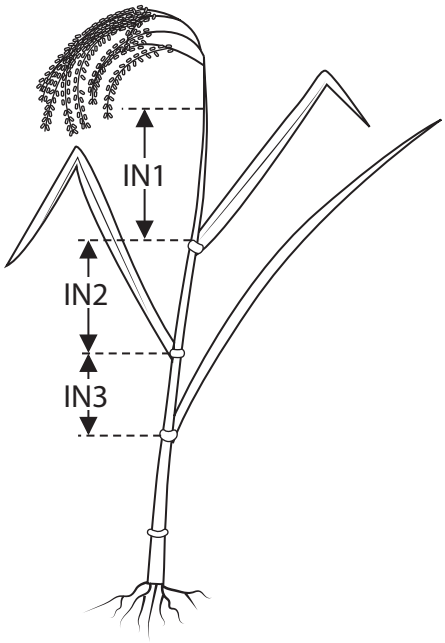
(b) The effect of a gibberellin on the growth of cereal plants was investigated.

Different concentrations of the gibberellin were sprayed on cereal plants.

The lengths of the first, second and third internodes (IN1, IN2, IN3) were measured, as shown in the diagram.



The table shows the effect of the gibberellin on the mean lengths of the first, second and third internodes.

Concentration of the gibberellin / ppm	Mean length / cm		
	first internode	second internode	third internode
0	36	19	14
10	36	19	14
100	41	21	14
1000	52	22	15
2500	56	22	15

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(i) Comment on the effect of the gibberellin on the growth of cereal plants.

(2)

(ii) Suggest how the gibberellin causes this effect.

(3)

(Total for Question 3 = 9 marks)

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4 Parkinson's disease is caused by a loss of neurones in part of the brain called the substantia nigra.

Co-beneldopa is used to treat Parkinson's disease.

Co-beneldopa is a mixture of L-dopa and a drug that prevents the conversion of L-dopa into dopamine in the blood.

(a) Explain why using Co-beneldopa will be more effective than using L-dopa alone to treat Parkinson's disease.

(3)

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(b) In an investigation, tomato plants were genetically modified to convert the amino acid tyrosine into L-dopa.

Three genes were used in this investigation:

- a control gene that is not involved in the production of L-dopa
- MYB12, a plant gene that produces a transcription factor
- CYP76, a gene found in beetroot that codes for an enzyme that converts tyrosine into L-dopa.

The table shows the concentration of L-dopa in the tomato fruit from genetically modified plants.

Genes used to modify the tomato plants	Concentration of L-dopa in the tomato fruit / mg 100 g^{-1}
none	1.2
control gene	1.2
MYB12	1.5
CYP76	10.2
CYP76 and MYB12	14.6

(i) Explain the effects of these three genes in this investigation.

(4)

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(ii) Describe how tomato plants could be genetically modified to make the enzyme that converts tyrosine to L-dopa.

(3)

(Total for Question 4 = 10 marks)

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5 The nervous system enables an organism to respond to environmental stimuli.

(a) Several types of neurone are found in the nervous system.

(i) Which term describes the space between a sensory neurone and a relay neurone?

(1)

☒ **A** axon

☒ **B** cell body

☒ **C** postsynaptic membrane

☒ **D** synaptic cleft

(ii) Compare and contrast the function of a sensory neurone and a motor neurone.

(3)

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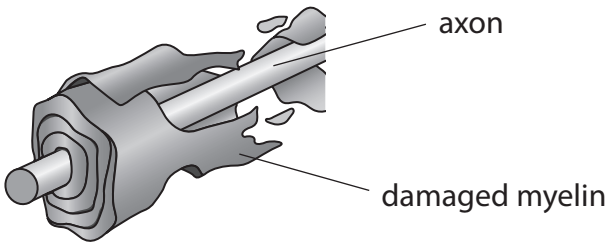
(b) Guillain-Barré syndrome is a disorder of the nervous system.

The immune system damages the myelin sheath surrounding the axons of individuals with Guillain-Barré syndrome.



Symptoms of this disorder include:

- inability to maintain steadiness when walking
- inability to feel any sensations in the limbs
- loss of reflexes such as knee jerk.

Suggest why a person with Guillain-Barré syndrome will suffer from the symptoms of this condition.

(3)

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(c) Mutations in the genes coding for voltage-gated calcium ion channels have been linked to neurological conditions.

Explain how these mutations might cause these neurological conditions.

(4)

(Total for Question 5 = 11 marks)

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6 The human body responds to changes in both its internal and external environments.

(a) How many of these statements describe the effects of adrenaline in the "fight or flight" response?

- arterioles constrict in skeletal muscles
- glycogen is released from the liver
- the rate of food digestion decreases

(1)

☒ **A** 0

☒ **B** 1

☒ **C** 2

☒ **D** 3

(b) The heart responds to adrenaline by increasing cardiac output.

Cardiac output = heart rate × stroke volume

(i) Calculate the cardiac output for a person who has a heart rate of 77 bpm and a stroke volume of 70 cm^3.

Give your answer to two significant figures in $dm^3\ hour^{-1}$.

(2)

Answer ..... $dm^3\ hour^{-1}$

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(ii) The formula shows how to calculate the cardiac index. This is a method of adjusting cardiac output values for the body surface area of an individual.

$$\text{cardiac index} = \frac{\text{cardiac output in dm}^3\,\text{min}^{-1}}{\text{body surface area in m}^2}$$

The table shows some information for cardiac output, body surface area and cardiac index for two individuals.

Individual	Cardiac output / $dm^3\,min^{-1}$	Body surface area / m^2	Cardiac index
A	6.7	1.92	
B		1.49	2.8

Complete the table to show the units for cardiac index, the cardiac index for individual A and the cardiac output for individual B.

(3)

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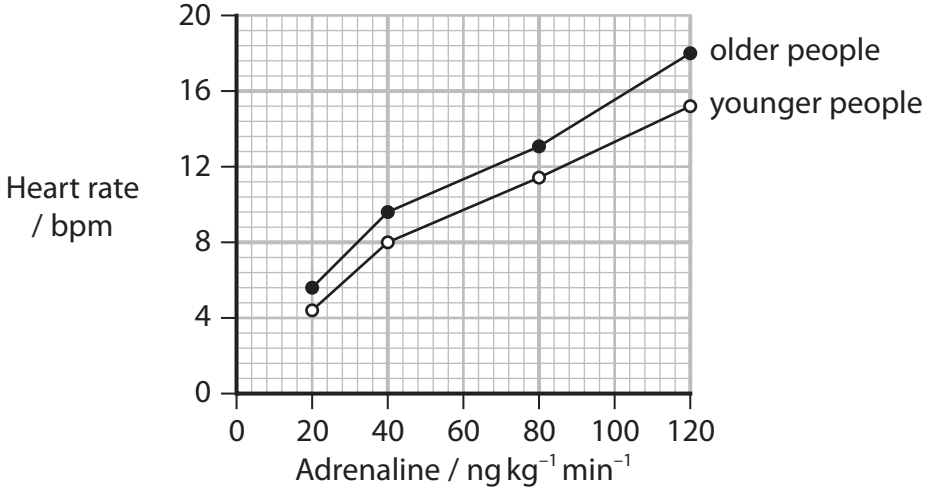
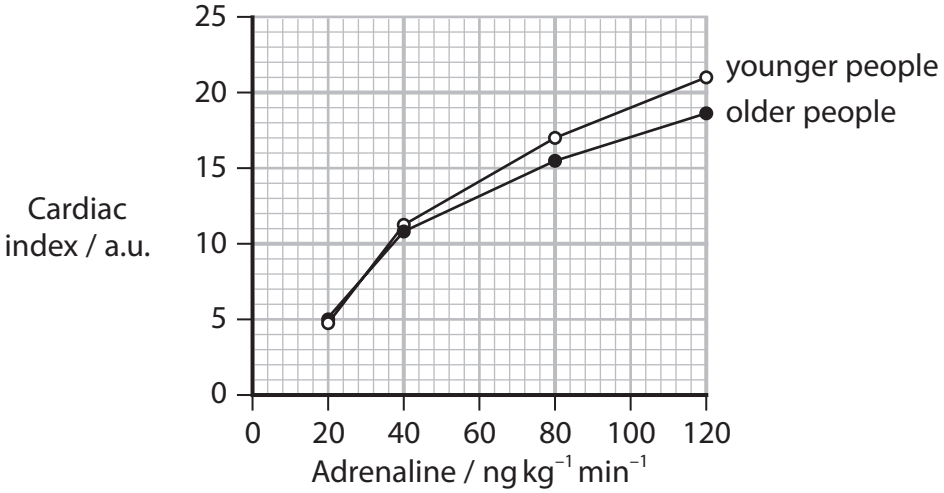
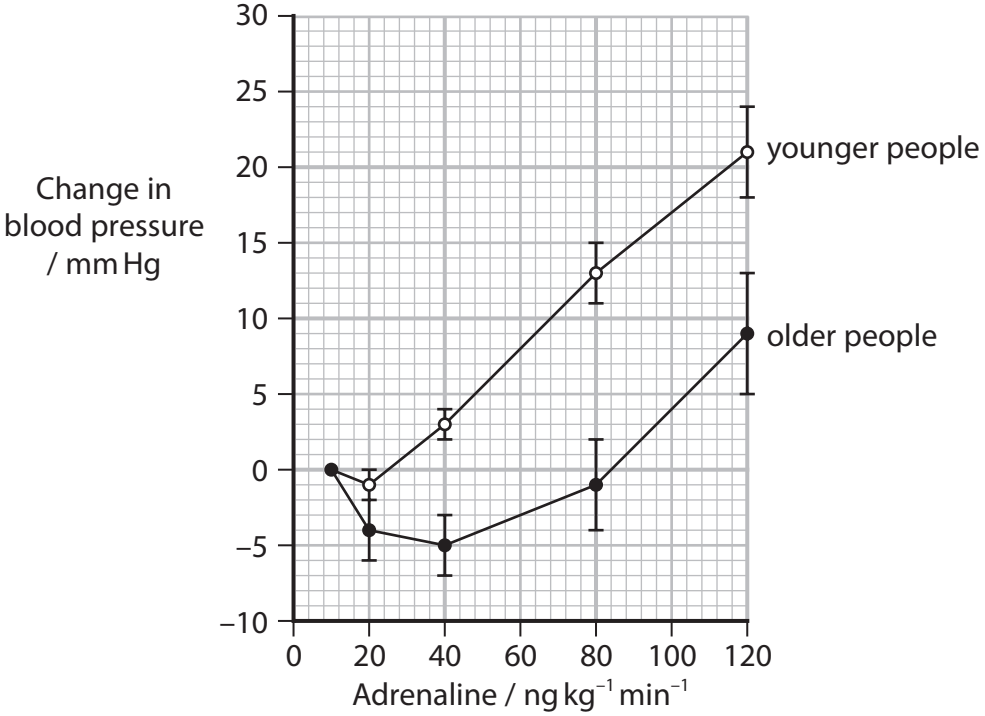
*(iii) Ageing is associated with changes in the way the heart responds to adrenaline.

In an investigation, the effects of adrenaline on the hearts of young people and old people were recorded.

The graphs show the results of this investigation.







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Discuss the effect of ageing on the response of the heart to adrenaline.

Use the information in the graphs to support your answer.

(6)

(Total for Question 6 = 12 marks)

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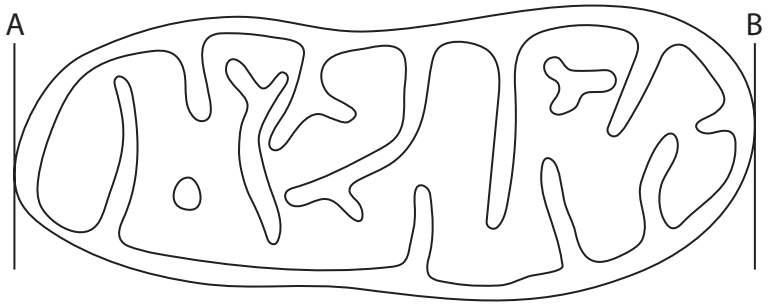
7 In eukaryotic organisms aerobic respiration takes place in mitochondria.

(a) The diagram shows a mitochondrion.



The actual length of the mitochondrion between A and B was 0.75 μm.

Calculate the magnification of the mitochondrion shown in the diagram.

Give your answer in standard form.

(2)

Answer .....

(b) In an investigation, the rate of production of carbon dioxide by mitochondria was measured.

Three samples of mitochondria had the following chemicals added to them:

- Sample 1: pyruvate
- Sample 2: pyruvate and ADP
- Sample 3: pyruvate and pyruvate transport inhibitor.

The table shows the results of this investigation.

Sample	Chemicals added	Rate of carbon dioxide production in 20 minutes / nmol per mg of mitochondria
1	pyruvate	62.6
2	pyruvate and ADP	85.0
3	pyruvate and pyruvate transport inhibitor	11.6

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(i) Which is the approximate rate at which carbon dioxide is produced in sample 1?

(1)

☒ **A** 3 nmol mg min

☒ **B** 180 nmol mg min

☒ **C** 3 nmol mg^{-1} min^{-1}

☒ **D** 180 nmol mg^{-1} min^{-1}

(ii) Explain the results of this investigation.

Use the information in the table and your own knowledge of the Krebs cycle to support your answer.

(4)

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(c) Fast twitch and slow twitch muscle fibres contain different numbers of mitochondria.

(i) Explain the difference in the number of mitochondria in these two types of muscle fibre.

(3)

(ii) Describe the role of ATP in muscle contraction.

(4)

(Total for Question 7 = 14 marks)

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8 The scientific document you have studied is adapted from articles in *StatPearls: Anatomy, Autonomic Nervous System, British Journal of Cardiology: Postural Orthostatic Tachycardia Syndrome (POTS)* and *Cellular and Molecular Life Sciences: The enteric nervous system in gastrointestinal disease etiology.*

Use the information from the scientific document and your own knowledge to answer the following questions.

(a) The autonomic nervous system regulates aspects of respiration (paragraph 1).

Describe how the autonomic nervous system regulates the breathing rate when a person is resting.

(4)

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(b) Explain how neurones can respond to different neurotransmitter substances (paragraph 4).

(3)

(c) Suggest how the activity of the sympathetic nervous system in immune organs could regulate inflammation (paragraph 7).

(2)

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(d) Explain how an electrocardiogram could be used to show that a person has postural orthostatic tachycardia syndrome (POTS) (Box 1).

(2)

(e) Explain how reflex circuits in the gut cause a bolus to move (paragraphs 10 and 11).

(4)

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(f) State what is meant by the term ischemia (paragraph 12).

(1)

(g) Suggest why embryological ENS cells may fail to colonise the bowel in a developing embryo (paragraph 13).

(1)

(h) Explain how the interaction of microbial and other factors could result in gastrointestinal inflammation such as IBD (Box 2).

(3)

(Total for Question 8 = 20 marks)

TOTAL FOR PAPER = 90 MARKS

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Time 1 hour 45 minutes

Paper reference **WBI15/01**

Biology

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

Scientific article for use with Question 8
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Scientific article for use with Question 8

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)