



# Physiological Objectives for Medical Students

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# Foreword

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Physiology is the science of life, and I am sure it is self-evident to many of you reading this document that in order to understand how and why the body goes wrong in disease, we have first to know how it operates in health.

Working alongside clinical colleagues, as many academic physiologists do, I am extremely fortunate in being able to draw connections between my research interests and the subjects I teach in order to provide a research-led education to healthcare professionals who will go on to have a direct impact on the treatment and care of patients. Time spent teaching physiology to medical students is becoming increasingly brief within a progressively crowded curriculum. It is therefore timely that The Physiological Society has recognised the need to support those responsible for teaching medical students the fundamental mechanisms of physiology that underpin their careers by providing specifically designed objectives for undergraduates.

The Physiological Society's 2019 policy report *Growing Older, Better* made a series of recommendations on interdisciplinary working including one that specifically related to raising the profile of physiology within medical and nursing curricula<sup>1</sup>. This was in response to concerns from both physiologists and medical practitioners that a decline in the understanding of physiology within the commonly adopted problem-based approach to learning in many medical schools could lead to unintended gaps in knowledge and thus deplete the resilience for reacting to unusual or rapidly changing medical circumstances.

The General Medical Council's GMC changes to the assessment of newly qualified doctors from 2023 and its accompanying guidance, *Outcomes for Graduates*, gives The Physiological Society an opportunity to build a dialogue with senior medical stakeholders.

This is not a new problem. Indeed, the core group that I chaired were extremely grateful to be able to build on the work of Richard Dyball and colleagues, who instigated a similar project on behalf of The Society over 10 years ago. It is a reflection of both the amount of knowledge required and the quality of expertise that exists within physiology that we were able to draw on a wealth of talent from across The Society to review and update the curriculum that was originally drafted by Richard and his team. We hope that this piece of work represents the beginning of The Society's engagement with organisations that represent healthcare professionals to ensure the skills and insight that physiology can offer make it from the laboratory to the bedside. In a year characterised by the emergence of a novel and deadly virus with symptoms that impact the whole human system, the need for medical students to understand fundamental physiology has never been more important.



## Prem Kumar

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<sup>1</sup> The Physiological Society, *Growing Older, Better*, October 2019

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# Introduction

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This document outlines a physiology curriculum for medical students. It details the physiological understanding we would expect doctors to have at the point of entry to F1.

The document is split into ten chapters. The first characterises the core concepts of physiology that medics must be able to apply to the remaining nine chapters, which all relate to systems within the body.

- 1 Core Concepts in Physiology
- 2 Cells and their Environment
- 3 Nervous System
- 4 Endocrine Regulation
- 5 Musculoskeletal System
- 6 Heart and Circulation
- 7 Kidney, Urinary System and Control of Body Fluids
- 8 Lungs and Gas Exchange
- 9 Gastrointestinal System
- 10 Reproductive System and Pregnancy

While each system has its own unique attributes, the document has been designed with uniform format across chapters as much as possible to aid with navigation of the document. As such, each chapter contains roughly 12 key points with additional information as required and includes a short final section at the end comprising a series of disease states that could be used to construct scenarios for problem-based courses.

## About The Physiological Society

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The Physiological Society has a 140-year tradition at the forefront of life sciences. When physiologists collaborate around the world, their research contributes to a better understanding of the complex functions of living organisms. Expanding physiological knowledge helps us to understand how the body works. It also helps us to determine what goes wrong in disease, facilitating the discovery of new diagnostics, treatments and preventative measures.

The Society's activities benefit the public in a variety of charitable ways. Our publications, meetings and educational resources directly benefit people actively involved in physiology such as researchers, teachers and students. This investment has a trickle-down effect by improving human health and broadening the public's understanding of how physiology relates to everyday life.

## 1

# Core Concepts in Physiology



At the point of entry to F1, doctors will be expected to have both knowledge and understanding of:

- 1.1 Physiology as the science which describes the function of cells and the organisational and functional relationships between cells, tissues, organs and body systems.
- 1.2 The concepts of homeostasis and allostasis.
- 1.3 The concepts of feedback and feedforward which are key to physiological regulation.
- 1.4 The concepts of physiological variation (genotype/phenotype), normal physiology and how physiology changes with healthy ageing through the course of life (fetal, neonatal, childhood, adolescence, adulthood).
- 1.5 Physiological adaptations to the environment (e.g. altitude, zero gravity [the impact of prolonged bed rest], diving) and in response to exercise and training in the context of healthy lifestyles.
- 1.6 Understanding normal physiology is facilitated by study of pathophysiology and vice versa.

# 2 Cells and their Environment



At the point of entry to F1, doctors will be expected to have both knowledge and understanding of:

- 2.1 Functional organisation of the cell into chemically distinct compartments separated by lipid membranes.
- 2.2 Composition and relative size of body fluid compartments; plasma, extracellular fluid (ECF) and intracellular fluid (ICF).
- 2.3 Movement of cations, anions and water across membranes; differential distribution, diffusion, ionotropic and metabotropic mechanisms, and co- and reciprocal transport. The  $\text{Na}^+/\text{K}^+$ -ATPase and its role in intracellular ion composition.
- 2.4 Movement of larger molecules across membranes; diffusion, active transport, endocytosis and exocytosis.
- 2.5 Concept of tonicity and how it is different from osmolarity.
- 2.6 Selective membrane permeability to ions and equilibrium potential: Ohm's law, the Nernst equation and the Goldman equation.
- 2.7 Resting membrane potential and the role of potassium.
- 2.8 Passive electrical conduction; resistance and leakage (space and length constant).
- 2.9 Graded (subthreshold) potentials, sensory transduction and summation.
- 2.10 The action potential and the sequence of ionic events that generate it; importance of the refractory period.
- 2.11 Conduction of the action potential, fibre types and myelination; compound action potential.
- 2.12 Measuring electrical activity and transport processes at the cell and whole-body levels.



Items that might be used to construct scenarios for problem-based courses:

Stopping the heart with bolus injection of  $\text{K}^+$ ; Shaker  $\text{K}_v$  channel which creates a shaking leg phenotype in *Drosophila* and is associated with episodic ataxia type 1 in humans; fainting goats and myotonia congenita as an exemplar of the importance of chloride; muscular weakness due to hypokalaemia; hypo/hypercalcaemia and acute hyponatraemia resulting in confusion and/or seizure due to movement of water into cerebral neurons by osmosis; cerebral oedema.



# 3 Nervous System

At the point of entry to F1, doctors will be expected to have both knowledge and understanding of:

**3.1** Information flow and organisation of the nervous system: central, peripheral and enteric nervous systems.

**3.2** The function of nerve cells and circuits.

**3.2.1** Neuronal structure (dendrites, synapses, cell body axons, glia, relationship to vascular system).

**3.2.2** Chemical neurotransmission: major excitatory (glutamate, serotonin, acetylcholine (ACh)) and inhibitory (GABA, glycine) neurotransmitters; ionotropic or metabotropic receptors define excitatory/inhibitory neurotransmission; postsynaptic potentials (excitatory postsynaptic current (EPSC)); presynaptic inhibition.

**3.2.3** Postsynaptic integration: synaptic convergence/divergence; temporal and spatial summation; plasticity.

**3.2.4** Simple neural circuits, reflexes (knee jerk reflex) and emergent properties of circuits.

**3.3** Sensory systems.

**3.3.1** Types and properties of sensory receptors (mechano-, thermo-, chemo-, photo-, nociceptors) and relation to senses (visual system, auditory system, vestibular system, olfactory system, pain, touch).

**3.3.2** The concepts of labelled lines, gating, receptive fields, lateral fields, adaptation and descending control; segmental innervation of the spinal cord; dermatomes.

**3.3.3** The major pathways for touch and pain, nociception, referred pain and phantom limbs.

**3.3.4** The structure and function of primary somatosensory cortex (S1); the somatotopic map, the homunculus.



### 3.4 Motor systems.

- 3.4.1 Control of movement (feedforward, fast/feedback, slow), proprioception; efference copy, the muscle spindle; co-ordination of movement at the spinal level.
- 3.4.2 The role of the basal ganglia (initiation of movement); cerebellum (motor learning); vestibular system (balance); reciprocal inhibition; oculomotor control.
- 3.4.3 Descending cortical control; ventromedial pathways; dorsolateral pathway.

### 3.5 The autonomic nervous system.

- 3.5.1 Opposing action of sympathetic nervous system (fight or flight response, arousal, energy generation, reduced digestion) and parasympathetic nervous system (rest and digest, enhancing digestion) through control of internal organs/glands.
- 3.5.2 Central autonomic control: hypothalamus, brain stem.

### 3.6 Higher brain function.

- 3.6.1 Learning and memory: episodic vs procedural memory; hippocampus, amygdala and cerebral cortex; navigation, place and grid cells.
- 3.6.2 Emotion, Papez (medial limbic) circuit and prefrontal cortex.
- 3.6.3 Decision making, impulse control: ventromedial prefrontal cortex/orbitofrontal cortex.



Items that might be used to construct scenarios for problem-based courses:

Glasgow coma scale, brain stem death, psychiatric disorders, common neurological tests (e.g. Babinski sign); multiple sclerosis, myelination, demyelination syndromes, spinal injury (complete and incomplete, autonomic dysreflexia), stroke, ageing, tinnitus, colour blindness; raised intracranial pressure (confusion, hypertension, bradycardia – Cushing effect); the sleeping brain and electroencephalogram (EEG); narcolepsy; the consequence of lesions of central pathways; disorders of higher brain function: dementia, schizophrenia, Alzheimer's disease.



# 4 Endocrine Regulation

At the point of entry to F1, doctors will be expected to have both knowledge and understanding of:

- 4.1 Information flow and organisation of the major endocrine systems (autocrine, paracrine, hormone receptors, feedforward, feedback, blood-brain barrier).
- 4.2 Importance of rhythmic output of hormones over multiple timescales (ultradian and circadian rhythms), pulse generation and disruption in disease.
- 4.3 Conventional grouping of hormones (peptides, steroids, eicosanoids), their receptors and signalling pathways.
- 4.4 Anterior pituitary control by hypothalamic hormones released into the hypophysial portal blood system:
  - 4.4.1 Adrenocorticotrophin (ACTH) regulation by corticotropin-releasing hormone (CRH), neuroendocrine response to stress and glucocorticoid release from adrenal cortex.
  - 4.4.2 Luteinising hormone (LH) and follicle stimulating hormone (FSH) regulation by gonadotrophin releasing hormone (GnRH) and control of hormones of the ovary (oestrogen, progesterone) and testes (testosterone).
  - 4.4.3 Growth hormone (GH) regulation by growth hormone regulating hormone (GHRH) and control of metabolism and growth.
  - 4.4.4 Prolactin (PRL), its hypothalamic control by inhibitory dopamine and its role as a pleiotropic hormone.
  - 4.4.5 Thyroid stimulating hormone (TSH), its hypothalamic control by thyroid releasing hormone (TRH) and control of thyroid function.
- 4.5 Posterior pituitary control by hypothalamic neuroendocrine neurones.
  - 4.5.1 Vasopressin (anti-diuretic hormone, ADH) and the control of plasma osmolality and drinking behaviour.
  - 4.5.2 Oxytocin control of milk-ejection, parturition and maternal bonding behaviour.

- 4.6** Adrenal gland.
- 4.6.1** Adrenal cortex and regulation of glucocorticoid, mineralocorticoid and aldosterone secretion.
  - 4.6.2** Adrenal medulla – neural control of fight-or flight response and release of adrenaline and noradrenaline.
- 4.7** Parathyroid gland; parathyroid hormone (PTH), control of plasma calcium and opposing effect of calcitonin from thyroid; bone mineralisation.
- 4.8** Pancreas; regulation of blood glucose and opposing actions of glucagon (alpha cells) and insulin (beta cells), diabetes and regulation of hormone output by somatostatin (delta cells).
- 4.9** Pineal gland: melatonin and regulation of circadian rhythms; sleep patterns.
- 4.10** Adipose; leptin and the control of satiety, energy balance and obesity.
- 4.11** Crosstalk between endocrine axes (e.g. endocrine control of growth and metabolism and diabetes; thyroid hormones, growth hormone, somatostatin, gonadal steroids, insulin, glucagon; brown adipose tissue and the hypothalamic control of temperature regulation; appetite and its control by the hypothalamus, adipose and gut; ventromedial and arcuate hypothalamic nuclei; leptin; ghrelin; cholecystokinin (CCK), pancreatic polypeptide, neuropeptide Y (NPY), glucagon-like peptides, orexin).
- 4.12** Programming and plasticity of endocrine axes.



Items that might be used to construct scenarios for problem-based courses:

Hypo- and hypersecretion by the thyroid; thyroiditis, post-operative hypothyroidism, Grave's, Addison's and Cushing's diseases, syndrome of inappropriate antidiuretic hormone secretion (SIADH), diabetes insipidus, iatrogenic parathyroid removal; osteoporosis, Paget's disease, osteoarthritis; type I and type II diabetes, metabolic acidosis in diabetic ketosis; athletic performance enhancement, dieting; pituitary tumours, acromegaly and gigantism, dwarfism (not achondroplastic); Sheehan's syndrome.



# 5 Musculoskeletal System

At the point of entry to F1, doctors will be expected to have both knowledge and understanding of:

- 5.1 Types of muscle.
- 5.2 Organisation of the musculoskeletal system (bone, tendon, ligaments).
- 5.3 Primary functions, structure and regulation of bone.
- 5.4 Functional structures: muscle, fascicle, fibres (fast/slow; type I/type II), myofibril; sarcomere, T-tubule, sarcoplasmic reticulum (SR).
- 5.5 The structure of the neuromuscular junction (NMJ) motoneuron, axon branch and endplate.
- 5.6 Thick and thin (myosin and actin) filaments within the sarcomere; how filaments generate movement and/or tension (role of calcium, ATP hydrolysis, excitation contraction coupling).
- 5.7 Isometric/isotonic contractions.
- 5.8 Function of the NMJ; pre-junctional role of voltage-gated  $\text{Ca}^{2+}$  channels; intracellular  $\text{Ca}^{2+}$  increase; ACh synthesised by acetyl transferase; vesicle fusion and release; ACh degradation in cleft by acetylcholinesterase in basal lamina. Diffusion of ACh and binding to receptors in postsynaptic membrane.
- 5.9 Channel opening leads to end-plate potentials (EPPs) that trigger propagating muscle fibre action potential (1-to-1 with the motoneuron action potential). Tetanic activation and electromyogram (EMG).
- 5.10 Pre- and post-synaptic modulation of the NMJ and contraction, e.g. channels, receptors and enzymes.
- 5.11 Structure and function of the motor unit.

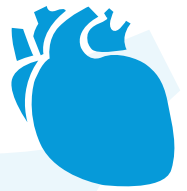
**5.12** Modulation of force: recruitment of motor units, action potential frequency, filament overlap, velocity of filament sliding, motor unit remodelling.

**5.13** Muscle metabolism, exercise, training and fatigue (phosphocreatine stores, anaerobic glycolysis and oxidation [range of converting energy to movement depending on activity type]).



Items that might be used to construct scenarios for problem-based courses:

Muscular dystrophies; myasthenia gravis; congenital myasthenic syndrome; Lambert–Eaton myasthenic syndrome; rhabdomyolysis due to muscle injury, e.g. crush syndrome causing hyperkalaemia and raised circulating creatine kinase; muscle relaxants at surgery; rigor mortis; myotonia; sarcopenia; frailty; tetanus; diseases of the bone; osteoporosis, Paget’s disease, osteoporosis and sarcopenia co-existence, leukaemia, osteomalacia, scoliosis, kyphosis, Relative Energy Deficiency in Sport (RED-S – formerly known as the Female Athlete Triad), acromegaly, osteoarthritis.



# 6 Heart and Circulation

At the point of entry to F1, doctors will be expected to have both knowledge and understanding of:

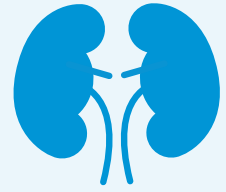
- 6.1 The organisation of the cardiovascular system (heart, blood and lymphatic vessels) and haemodynamics (relationship between blood pressure, flow and resistance).
- 6.2 Blood composition and the role of the different blood cells (erythrocytes, leukocytes) and plasma components (platelets, pro- and anti-coagulant factors) in blood flow (e.g. haematocrit) and haemostasis.
- 6.3 The physiology of cardiac muscle and specialised cells (sino-atrial and atrio-ventricular nodes) in relation to the generation and propagation of electrical activity (the ionic basis of different cardiac action potentials, gap junctions, T-tubules) and organised muscle contraction ( $\text{Ca}^{2+}$ , sarcoplasmic reticulum, actin-myosin interaction).
- 6.4 The electrical (electrocardiogram (ECG) and the main waves/complexes), pressure (ventricular, atrial, aortic, pulmonary arterial and venous jugular) and ventricular volume changes associated with the cardiac cycle (changes in ventricular, atrial and great vessel pressure, and ventricular volume with time and ventricular P-V loops) including the opening and closing of valves (heart sounds and murmurs), the jugular venous pulse and peripheral pulses.
- 6.5 The intrinsic (length-tension relationship) and autonomic (sympathetic and parasympathetic nerves)/hormonal control of cardiac output by alterations in stroke volume (end diastolic volume – end systolic volume) and/or heart rate.
- 6.6 The physiology and control of vascular smooth muscle (myogenic tone, autoregulation, autonomic, hormonal and local control mechanisms), the role of the endothelium (vasoconstrictors, vasodilators, the impact of oxidative stress) and adaptations to particular circulations as related to their functions (cerebral, coronary, pulmonary, skeletal muscle and skin).
- 6.7 The role of the microcirculation (capillaries) as a site for exchange (diffusion) between the blood and tissues, and in the generation of tissue fluid and lymph (Starling's forces and fluid filtration/reabsorption).
- 6.8 The features of elastic arteries as related to their function (elastin, collagen) and the determinants of systolic, diastolic and mean arterial blood pressure, pulse pressure, aortic stiffness and pulse-wave reflection, particularly in relation to the ageing of the cardiovascular system.

- 6.9** The short-term control of blood pressure (including the impact of posture/ gravity on venous return) by the arterial baroreceptors and the role of the autonomic nervous system and hormones.
- 6.10** The long-term control of blood pressure (control of blood volume [Atrial natriuretic peptide (ANP) and Brain natriuretic peptide (BNP)] and renal mechanisms [RAAS]) and the integration of the cardiovascular system with other systems.



Items that might be used to construct scenarios for problem-based courses:

Heart failure; congenital abnormalities; deep vein thrombosis (DVT); pulmonary embolism (PE); arrhythmias (including atrial fibrillation); myocardial infarction (MI); angina; valvular disease; aortic dissection; the use of ECG for diagnosis; shock and haemorrhage; hypertension; anaemia; oedema and its causes; abnormal clotting and bleeding (coagulation factors and anticoagulants, fibrinolysis); congenital abnormalities.



# 7 Kidney, Urinary System and Control of Body Fluids

At the point of entry to F1, doctors will be expected to have both knowledge and understanding of:

- 7.1** The structure and respective roles of the components of the urinary system (ureter, bladder, urethra) and the kidney (the nephron [cortical and juxtamedullary]), glomerular capsule, proximal and distal convoluted tubule, loop and collecting ducts and its blood supply (glomerular capillaries, afferent and efferent arterioles, vasa recta).
- 7.2** Tubular transport and the main mechanisms of reabsorption and secretion in the renal tubule (including tubular transport maxima).
- 7.3** Glomerular filtration and how it is governed by hydrostatic and oncotic forces including the role of afferent and efferent arterioles in the control of glomerular filtration rate (GFR), and how it can be measured (the concept of clearance, fractional excretion and reabsorption).
- 7.4** The function of the proximal tubule, including the reabsorption of glucose, bicarbonate, amino acids, phosphate,  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$ , urea and water, and small molecular weight protein transport.
- 7.5** The function of the loop (descending and thick ascending limb), and the role of the counter-current mechanism, counter current exchange and the vasa recta in establishing interstitial osmolarity ( $\text{Na}^+$ - $\text{K}^+$ -ATPase).
- 7.6** The function of the early and late distal tubule and collecting duct in the control of plasma osmolality, blood volume and urine production (including the role of antidiuretic hormone (ADH), aquaporins, urea, renin-angiotensin-aldosterone system, regulation of  $\text{Na}^+$  reabsorption, secretion of  $\text{K}^+$ ).
- 7.7** The mechanism of micturition and the control of bladder function including detrusor muscles (autonomic innervation) and sphincters, bladder stretch receptors, the micturition reflex and the contribution of higher centres/voluntary control.

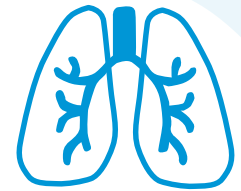


- 7.8** The neuroendocrine functions of the kidney including control of blood volume and osmolality,  $\text{Ca}^{2+}$ , parathyroid hormone (PTH), vitamin D, phosphate, fibroblast growth factor-23 (FGF-23), erythropoietin (EPO) and atrial natriuretic peptide (ANP).
- 7.9** The role of the kidney in acid-base regulation (ammonium, phosphate and excretion of acid equivalents).



Items that might be used to construct scenarios for problem-based courses:

Maintenance of circulating volume after haemorrhage and in shock; acute and chronic renal failure, causes, symptoms, treatments; glycosuria in diabetes; diabetes insipidus and causes of hyponatraemia; diuretics including loop diuretics, thiazide diuretics,  $\text{K}^{+}$ -sparing diuretics; consequences of impaired renal function; the effects of hyperaldosteronism; acid-base disturbances.



# 8 Lungs and Gas Exchange

At the point of entry to F1, doctors will be expected to have both knowledge and understanding of:

- 8.1** The organisation of the respiratory system as it relates to respiratory movements and the conditioning of air, and in relation to diagnostic examinations and procedures (larynx, upper and lower respiratory passages and thoracic and diaphragmatic topography, pleural membranes, airway surface liquid and mucus, how particles are cleared from the airways; macrophages and phagocytic cells).
- 8.2** The physical processes that underlie airway resistance in health and disease and the maintenance and control of airway tone and how these are assessed in lung function tests (airflow, convection, partial pressures and diffusion, bronchiole diameter, bronchial smooth muscle, parasympathetic nervous system, bronchodilator, asthma, bronchitis, lung volumes and capacities, peak flow, spirometry, FEV1, flow-volume loops, obstructive disease, restrictive disease).
- 8.3** Movement of the chest wall and diaphragm, the gas laws and ventilation (intrapleural pressure and lung volume changes during a respiratory cycle, pneumothorax, the concept of lung and thoracic cage compliance, surface tension and the role of surfactants, tidal volume, respiratory frequency, total ventilation, dead space and alveolar ventilation).
- 8.4** Gas exchange across the alveolar-capillary membrane and the impact on arterial blood gas tensions of regional and generalised variations in lung ventilation and perfusion ( $V/Q$ ) (functional microanatomy of the blood gas barrier, Henry's law, pulmonary diffusing capacity, diffusion constant perfusion and diffusion limitations, determinants of the  $V/Q$  ratio,  $V/Q$  matching and mismatch, dead space ventilation and shunt, alveolar-arterial partial pressure differences, physiological properties of the pulmonary vasculature, hypoxic vasoconstriction, hydrostatic pressure, pulmonary oedema).
- 8.5** The carriage of oxygen in blood and the impact of respiratory disease upon blood oxygen tensions (dissolved oxygen, functional importance of haemoglobin, oxygen content, pressure and saturation, oxyhaemoglobin dissociation curve, Bohr shift, 2,3-BPG oxygen delivery, oxygen capacity, alterations in genetic variants of haemoglobin, hypoxia, carbon monoxide poisoning and anaemia).

- 8.6** The carriage of carbon dioxide in blood, the role of the bicarbonate buffer system in pH regulation in health and in acid–base disturbances (carbamino compounds, bicarbonate, carbonic anhydrase, Haldane effect, CO<sub>2</sub> dissociation curve, pH, Henderson–Hasselbalch equation, blood buffers, metabolic and respiratory acidosis and alkalosis, Davenport diagram, metabolic and respiratory compensation).
- 8.7** Respiratory rhythmogenesis and drugs acting on central respiratory function (behavioural vs metabolic control, effectors, brain stem, central neural processes involved in respiratory pattern generation, respiratory rhythm, respiratory oscillators and networks, dorsal respiratory group (DRG) and ventral respiratory group (VRG), Botzinger complex, higher centre control, respiratory depressants and stimulants, general anaesthetic, opioids, anxiolytics).
- 8.8** Role of chemical and mechanical reflexes in modulating the respiratory pattern (peripheral chemoreceptor, carotid body and O<sub>2</sub> and H<sup>+</sup> sensing, central chemoreceptor and CO<sub>2</sub> sensing, ventrolateral medulla, ventilatory reflexes to blood gas alterations [airway mechanoreceptors, stretch receptors, Hering–Breuer reflex, irritant receptors, J-receptors, cough]).
- 8.9** The physiological and anatomical basis of respiratory disease leading to hypoxaemia and hypercapnia (airflow limitation, dynamic compression of airways, hypoventilation, obstructive and restrictive disease, type I and type II respiratory failure, asthma, chronic obstructive pulmonary disease (COPD), pulmonary embolism, pneumonia, assisted ventilation).
- 8.10** Matching oxygen supply to demand in a variety of physiological and pathophysiological situations (metabolic rate, exercise, oxygen demand, impact of ageing, fetal lung, altitude, diving).



Items that might be used to construct scenarios for problem-based courses:

Pneumothorax, (tension pneumothorax) asthma, chronic obstructive pulmonary disease (COPD), ‘hayfever’ and allergic respiratory disease, anaesthesia, sports medicine, altitude physiology; atelectasis, cardiac asthma, the mechanisms of action of broncho-dilators and anti-inflammatory drugs, lung function in premature babies; pulmonary embolic disease; obstructive sleep apnoea syndrome, central sleep apnoea in heart failure, obesity hypoventilation syndrome; neuromuscular diseases; exercise; breath-holding (apneists); Acute respiratory distress syndrome (ARDS); COVID-19; development of pulmonary oedema; hypoxic pulmonary vasoconstriction; anaemia, CO poisoning; genetic variance of haemoglobin; cough.

# 9 Gastrointestinal System



At the point of entry to F1, doctors will be expected to have both knowledge and understanding of:

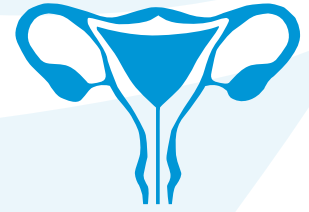
- 9.1** The structure, function, organisation and interaction of the gastrointestinal system; hollow organs (mouth, oesophagus, stomach, small and large intestine, rectum, anal canal) separated by sphincters (upper and lower oesophageal, pyloric, ileo-caecal, internal and external anal) with accessory organs (teeth, salivary glands, pancreas, liver, gall bladder).
- 9.2** The structure and function of the gut wall. Characteristic layered structure; mucosa (epithelium, lamina propria, muscularis mucosae); submucosa (includes blood vessels), muscularis externa (enteric nervous system; submucosal and myenteric plexuses), serosa (connective tissue).
- 9.3** The mechanisms of gastrointestinal motility, including role of neural and hormonal stimuli. Role of autonomic innervation: generalisation that sympathetic is inhibitory and parasympathetic excitatory. Motor activity underlying swallowing reflex (voluntary and autonomic reflex), sphincter control (motor, autonomic, distension), segmentation, peristalsis, migrating motor complexes, defecation (voluntary and involuntary control) and emesis (neural pathways).
- 9.4** Gastrointestinal hormones and paracrine agents; roles of secretin, gastrin, cholecystikinin, ghrelin, incretins, histamine, somatostatin, prostaglandins, serotonin and enkephalins.
- 9.5** Salivary function – role of mastication, regulation of output from salivary glands, composition of secretions.
- 9.6** Gastric function – control of accommodation, relative roles for chief (pepsinogen), parietal (acid secretion,  $H^+/K^+$ -ATPase), mucus and endocrine (gastrin, secretin) cells in the production of gastric secretions.
- 9.7** Pancreatic function – including exocrine (enzymes and bicarbonate) and endocrine (insulin, glucagon) pancreas, relative roles of acinar and duct cells to produce pancreatic fluid.
- 9.8** Liver function – organisation of biliary network and triad structures, production of bile acids (cholesterol, primary and secondary bile acids) and bile flow (secretin), gallbladder as a storage organ under hormonal control (cholecystikinin (CCK)); Role of enterohepatic circulation and route for bilirubin excretion; capacity for liver regeneration.

- 9.9** Small and large intestine function – small intestine organisation (duodenum, jejunum and ileum), role of villi (for absorption) and crypts (Lieberkühn); large intestine organisation (caecum, colon, rectum and the anal canal) and role in the absorption of water and solutes.
- 9.10** Control of digestion – considered as phases of digestion; cephalic, gastric and intestinal phases highlighting integrated control of salivary, gastric and pancreatic secretion. Duplication of function. Protein digestion achieved using pepsins and pancreatic proteases; brush-border enzymes. Carbohydrate digestion achieved using salivary and pancreatic amylases. Fat digestion achieved using lipases and bile acids (emulsification). Digestive products and water absorbed by the intestinal brush border (diffusion, carriers, channels).
- 9.11** Gastrointestinal health – control of appetite (dietary intake), role of dietary fibre (cellulose, lignin) which is not absorbed, role of the microbiome.



Items that might be used to construct scenarios for problem-based courses:

Bariatrics and use of stomas; xerostomia, Sjogren's syndrome, salivary glands; dysphagia; acid reflux; gastric ulceration, role for *Helicobacter pylori*, treatment (antibiotics, H<sub>2</sub>-receptor and H<sup>+</sup>/K<sup>+</sup>-ATPase antagonists); cystic fibrosis, cholera and chloride; pernicious anaemia and role of vitamin B12; Hirschsprung's and Chagas diseases, effects on the enteric nervous system (ENS); bowel incontinence, constipation and diarrhoea; gastrointestinal neuroendocrine tumours, e.g. Verner–Morrison syndrome, Zollinger–Ellison syndrome; lactose intolerance; jaundice; liver cirrhosis and alcoholism; pancreatic failure and steatorrhoea; inflammatory bowel disease, ulcerative colitis, Crohn's disease.



# 10 Reproductive System and Pregnancy

At the point of entry to F1, doctors will be expected to have both knowledge and understanding of:

- 10.1 The structures and organisation of the male (testis, seminal vesicle, prostate gland, bulbourethral glands, penis) and female (ovaries, salpinges, uterus, vagina) reproductive systems.
- 10.2 Sex determination, sexual differentiation (genetic aspects) and the biology of intersexes (chromosomal and hormonal).
- 10.3 Puberty, gamete production and transport, fertilisation, implantation and pregnancy, and the effects of age on fertility; menarche, menopause.
- 10.4 Control of sexual function; female reproductive hormones (Gonadotropin-releasing hormone (GnRH), luteinizing hormone (LH), follicle-stimulating hormone (FSH), oestrogen, progesterone, prolactin) and the ovarian cycle. Male hormones (testosterone LH, FSH and inhibin).
- 10.5 Placental function and changing nutrition patterns during pregnancy; placenta hormones (Human chorionic gonadotropin (hCG) and steroids) and transport mechanisms ( $O_2$ ,  $CO_2$ , solutes).
- 10.6 Maternal adaptations during pregnancy (e.g. endocrine, body weight, cardiovascular).
- 10.7 Control of fetal heart and circulation; effects of autonomic development, role of shunts, gas transport.
- 10.8 Parturition and its initiation; positive feedback mechanisms, role of prostaglandins and oxytocin..

- 10.9** Neonatal physiology (fetal haemoglobin, circulation, nutrition, thermoregulation).
- 10.10** Control of lactation; organisation of alveolus, lactogenic hormones (prolactin, insulin) and milk formation; implication for energy homeostasis.



Items that might be used to construct scenarios for problem-based courses:

Pre-eclampsia; infertility; pregnancy testing, testing for abnormalities, alpha fetoprotein (neural tube defects), hCG (trisomy 21), gestational diabetes, common interventions during labour (induction of parturition, Caesarian section), congenital adrenal hyperplasia, problems of prematurity, congenital heart lesions; the physiological basis of contraception; the physiological basis of common reproductive disorders; environmental impacts on fertility; developmental origins of adult disease; menarche and menopause.

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*Note: The numbers following a term in the index refer to the chapter and specific point within that chapter the term can be found (i.e. 8.4 refers to chapter 8, point 4). 'PBC' refers to the 'scenarios for problem-based courses' box at the end of each chapter, with the number referencing the chapter where it can be found (i.e. PBC 9 refers to the 'scenarios for problem-based courses' box in chapter 9).*

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