OHS Body of Knowledge

The Human as a Biological System

Core Body of Knowledge for the Generalist OHS Professional

Second Edition, 2021

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Bibliography

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The Human as a Biological System

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Core Body of Knowledge for the Generalist OHS Professional

The Human as a Biological System

Abstract

To be able to provide appropriate advice on the effects of hazards on workers' health and to competently assess the potential impacts of changes in the workplace, the generalist OHS professional requires a working knowledge of the physiology of the human body including the systemic interactions that may impact on the body's response to environmental exposures. After a brief history of the association of workplace exposures with worker health and wellbeing, this chapter presents an overview of the biological systems of the human body. Four case studies – featuring the nervous system, the integumentary system, the reproductive system, and the interaction between exposure to psychosocial hazards and multiple biological systems – provide examples of the application of physiological knowledge in the OHS context.

Keywords

system, nervous system, respiratory system, endocrine system, reproductive system, digestive system, skin, musculoskeletal

Contextual reading

Readers should refer to 1.2 Contents for a full list of chapters and authors and 1.3 Synopsis of the OHS Body of Knowledge. Chapter 2, *Introduction* describes the background and development process while Chapter 3, *The OHS Professional* provides a context by describing the role and professional environment.

Terminology

Depending on the jurisdiction and the organisation, Australian terminology refers to 'Occupational Health and Safety' (OHS), 'Occupational Safety and Health (OSH) or 'Work Health and Safety' (WHS). In line with international practice this publication uses OHS with the exception of specific reference to the Work Health and Safety (WHS) Act and related legislation.

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1 Introduction

The primary aim of the generalist occupational health and safety (OHS) professional is to safeguard the health and safety of workers and to promote a safe and healthy working environment. To achieve this aim, the generalist OHS professional must have a knowledge and understanding of how humans interact with work and the work environment, and how work exposures can affect humans. These interactions are complex. Injury and impairment to human biological systems may be acute and immediate or may occur gradually, only becoming apparent after a significant latency period. They may be a result of a single or of cumulative exposures. Work exposure to a particular hazard may impact a single physiological system, several systems, or there may be interlinking or synergistic impacts beyond the primary system(s) affected.

Understanding the impact of work exposures requires an understanding of the various physiological systems of the human body while also recognising that the human body is a biological system in itself. The OHS Body of Knowledge chapter *Systems* (Salmon, Read & Hulme, 2021) discusses the characteristics of systems with the key feature being that:

> …[Systems} are made up of a large number of heterogeneous elements; these elements interact with each other; the interactions produce an emergent effect that is different from the effects of the individual elements alone; and, this effect persists over time and adapts to changing circumstances. (Luke & Stamatakis, 2012, p. 2)

Thus the impact of hazardous work exposures is not only the impact on an individual physiological system (i.e., respiratory system, nervous system, musculoskeletal system) but is the interaction of these 'elements' or systems to produce an outcome that may be different from that of the initial target physiological system.[1] This interaction is not only persistent over time but can change and adapt, perhaps with negative or positive outcomes. It is vital that OHS professionals have an appreciation of these processes, such that adverse health outcomes can be anticipated and prevented or mitigated.

This chapter examines humans as biological systems and provides examples of why knowledge of these systems is vital to the provision of accurate OHS advice. Firstly, the chapter considers the relationship between workplace exposures and the health of workers from a historical perspective. This is followed by an overview of the biological systems of the body (i.e., the integumentary, cardiovascular/circulatory, respiratory, digestive, urinary, nervous, endocrine, lymphatic, immune, reproductive and musculoskeletal systems). Four case studies provide examples of the application of physiological knowledge to situations that a generalist OHS professional could encounter highlighting the systemic interactions. This chapter, like others in the OHS Body of Knowledge, is not intended as a textbook nor does it purport to address all the physiological knowledge important for an OHS professional

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[1] See for example *OHS BoK* 16 Work-related Musculoskeletal Disorders.

to understand the human as a biological system. Furthermore, an understanding of the human requires an understanding of psychological and social interactions, which also have a biological basis.[2]

This chapter on the human as a biological system should be read in conjunction with other chapters to provide a comprehensive overview of the topic area. Figure 1 below provides a road map to other related chapters.

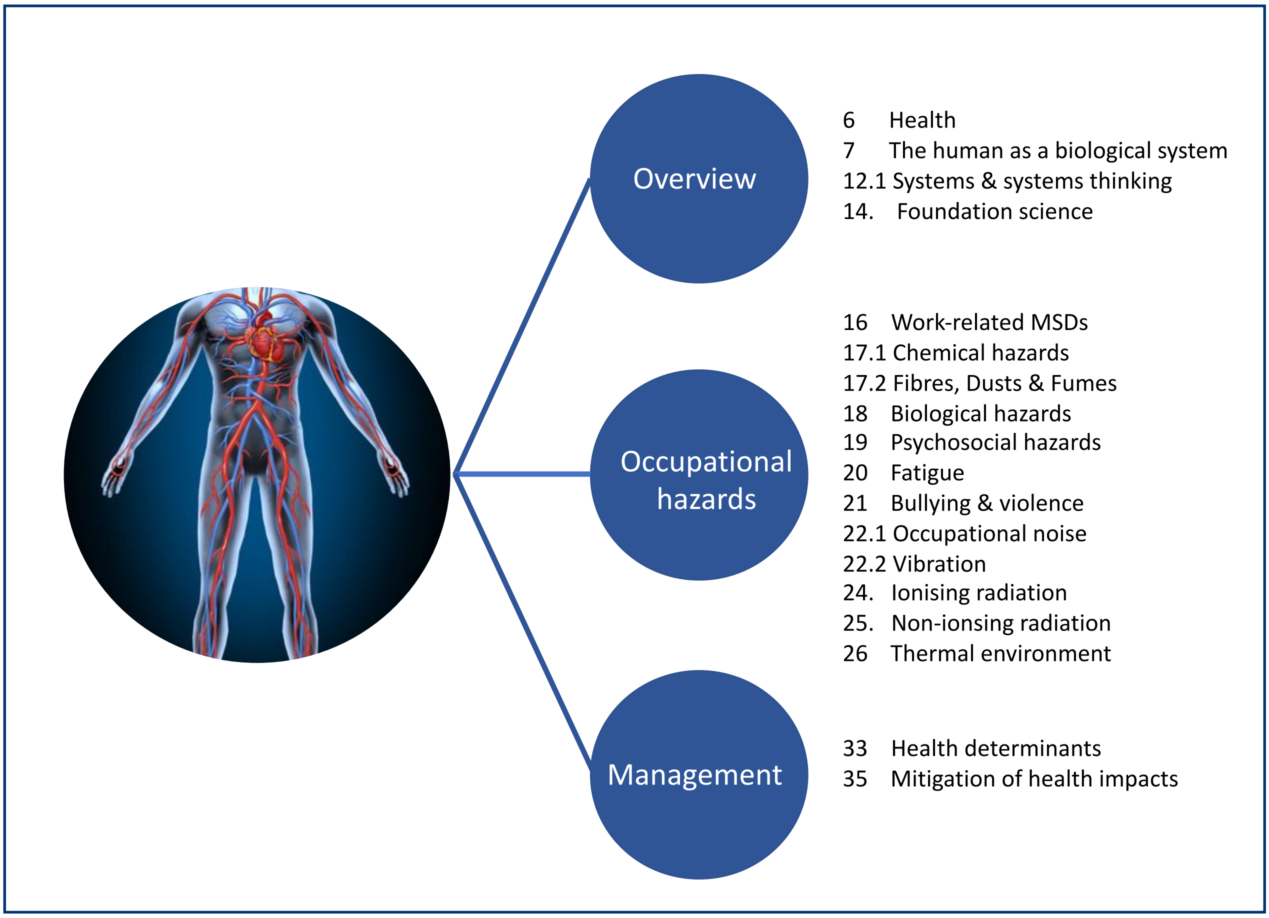

Figure 1: Guide to related chapters within the OHS Body of Knowledge

[2] See *OHS BoK* 8 series of chapters on psychology (in planning at time of writing).

2 Historical perspective

The importance of understanding the relationship between the human body and work is made clear by a brief look at the history of occupational health.

It is recorded that miners in ancient Egypt wrapped themselves in sacks and used masks made of the bladders of animals for dust protection (Škrobonja & Kontošić, 2002). In ancient Greece and Rome, physicians including Hippocrates and Pliny the Elder commented on the hazards of mining and other trades (Gochfeld, 2005). In *Oeconomicus* (circa 362 BC), Greek historian and philosopher Xenophon attributed the following description of the effects of working a trade to Socrates:

> What are called the mechanical arts," says Socrates, "carry a social stigma and are rightly dishonoured in our cities. For these arts damage the bodies of those who work at them…by compelling the workers to a sedentary life…in some cases to spend the whole day by the fire. This physical degeneration results also in deterioration of the soul…And in some cities, especially the warlike ones, it is not legal for a citizen to ply a mechanical trade…"
> (Xenophon as cited in Farrington, 1947, pp. 28–29)

Written by physician Ulrich Ellenbog in 1473, an eight-page pamphlet titled *Concerning the poisonous evil vapours and fumes of metals, such as silver, quicksilver, lead and others which the worthy trade of the goldsmith and other workers are compelled to use: How they must conduct themselves concerning these matters and how to dispel the poison* provided advice for German metalworkers (Smith, 2010):

> Wherefore when ye masters and men work silver with lead, or gild [which would use mercury], ye shall guard yourselves as far as ye may from the vapour and smoke, for it is poisonous to you, and it is my advice that ye do it in the open air with all diligence, and not in a closed room. Also ye shall not bend too much over this vapour but turn away therefrom and bind up the mouth. This vapour of quicksilver, silver, and lead is a cold poison, for it maketh heaviness and tightness of the chest, burdeneth the limbs and oft-times lameth them as one often seeth in foundries where men do work with large masses and the vital inward members become burdened therefrom. (Ellenbog as cited in Blanc, 2007, p. 199)

Italian physician and professor of medicine Bernardino Ramazzini is generally recognised as the founding 'father' of occupational medicine as a result of his systematic examination of the effects of workplace issues on human health in *De Morbis Artificum Diatriba* (*Diseases of Workers*), first published in 1700 (Pope, 2004; Škrobonja & Kontošić, 2002). Ramazzini's advice to physicians included:

> When you come to a patient's house, you should ask him what sort of pains he has, what caused them, how many days he has been ill, whether the bowels are working and what sort of food he eats…I may venture to add one more question: what occupation does he follow? (Ramazzini as cited in Pope, 2004, p. 2336).

Ramazzini's description of lung disease arising from dust exposure demonstrated his recognition of the reaction and interaction of various body systems in response to a hazard (dust):

> [T]he men who sift and measure are so plagued by this kind of dust that when their work is finished they heap a thousand curses on their calling. The throat, lungs and eyes are keenly aware of serious damage; the throat is choked and dried up with dust, the pulmonary passages become coated with crust formed by dust and the result is a dry and obstinate cough, the eyes are much inflamed and watery and almost all who make a living by sifting grain are short of breath and cachectic and rarely reach old age. (Ramazzini, as translated by Wright, 1940)

In addition to his focus on occupational exposures to toxic materials, Ramazzini described musculoskeletal problems related to sedentary work. He also recognised problems associated with repetitive motions and excessive manual materials handling (Pope, 2004). The precision of his clinical descriptions of the diseases and conditions associated with the occupations of his time have seen Ramazzini credited with pioneering not only occupational medicine, but also related disciplines such as epidemiology, environmental health, sports medicine and ergonomics (Škrobonja & Kontošić, 2002; Valentin as cited in Pope, 2004).

Thereafter, pockets of occupational research around the world began to reflect a growing interest in the health of workers. In the mid-1700s, for example, physician Jovanni Scopoli described the symptoms of chronic mercury poisoning in workers in a mercury mine in Idria, Slovenia, suggesting preventative measures and "confirmed Jussieu's observations that alcohol could greatly intensify the risk of intoxication with mercury" (Slavec, 1998, p. 55). In 1775, English surgeon Percival Pott observed a high incidence of scrotal cancer in London chimney sweeps and attributed this to "a lodgment of soot in the rugae of the scrotum" (Pott as cited in Doll, 1975, p. 522), providing the first clear description of an environmental cause of cancer (Doll, 1975, p. 521).

The 1800s saw the rise of health problems associated with the new industrial towns, including overcrowding, poor sanitation and poverty, and the health effects of work became matters of public interest (Carter, 2004; Gochfeld, 2005). In the UK in the 1860s, data from the registration of causes of death (started in 1836) were used by John Simon, the Medical Officer of the Privy Council, to report that the risks of death from lung disease were highest "where many were engaged in dusty jobs, such as metal grinding, coal, iron, textiles and mining" (Carter, 2004). Also in the 1860s, the first regulatory requirements for ventilation in workplaces were introduced, and the bacterial causes of infectious illness began to be recognised, allowing for the application of specific remedies to particular diseases (Carter, 2004).

As identified by Smith (2010), important post-Ramazzini publications that advanced the body of knowledge on occupational health included Thackrah's 1831 *The Effects of Arts, Trades* *and Professions*; McCready's 1837 *On the Influence of Trades, Professions, and Occupations in the United States, in the Production of Disease*; Brigham's 1875 *The Influence of Occupations Upon Health*; White's 1915 *Occupational Affections of the Skin*; Collis's 1921 *The Health of the Industrial Worker*; and Hamilton's 1925 *Industrial Poisons in the United States* and 1943 *Exploring the Dangerous Trades.* Influential mid 20th century publications included Patty's *Industrial Hygiene and Toxicology* and Hunter's *Diseases of Occupations.*

Since the late 1800s, there have been great advances in science, toxicology, occupational medicine, occupational hygiene, OHS legislation and practice and, as a result, the standards of OHS in developed countries has vastly improved. Our modern world benefits from the work of past physicians, scientists and others who have studied the effects of workplace exposures and working conditions on humans. As a result, the effects of workplace exposure to chemicals, such as lead, benzene, asbestos, silica and solvents, are well characterised. Unfortunately, this knowledge has come at the expense of many lives with developments generally arising from experiences of death and disease. The challenge for OHS into the future is to identify new hazards, and to ensure we recognise existing hazards in new forms, before they cause ill health (Gochfeld 2005).

Significantly, the occupational hygiene profession includes the term 'anticipation' in their definition of the role of an occupational hygienist. Informed anticipation is vital to help prevent fatality, injury, disease or ill health from accompanying new and emerging technologies. Another global challenge facing OHS concerns workplace conditions in developing countries where workers still face conditions not unlike those of the early Industrial Revolution. This is an issue that will challenge the global OHS community well into the future.

We must not be lulled into a false sense of security with the belief that these diseases have been confined to history. In the last 10 years we have seen the re-emergence of silicosis, including its most severe forms in stone benchtop workers in Australia, Israel, Turkey and a number of other countries (Hoy, 2018). Knowledge of the biological systems of the body, their action and interaction, is vital in enabling the generalist OHS professional to maintain awareness of the impact of workplace exposures and to appreciate the potential complexity of the body's response to such exposures.

3 Biological systems of the body

The human body is a complex organism. Its structures and functions can be understood at various levels – chemical (e.g., a molecule in the membrane that encloses a cell), cellular (e.g., a cell in the stomach lining), tissue (e.g., layers of tissue in the stomach wall), organ (e.g., stomach), body system (e.g., digestive system) and organism (i.e., the whole body) (Sherwood, 2010). In this context, a 'system' can be defined as "a group of body organs or structures that together perform one or more vital functions" (Merriam-Webster, 2012).

The systems within the body interact to maintain *homeostasis*, which "is essential for the survival of each cell, and each cell, through its specialised activities, contributes as part of a body system to the maintenance of the internal environment shared by all cells" (Sherwood, 2010, p. 10). Disruptions in homeostasis, which occur when one or more body systems malfunction, can threaten cell survival and lead to illness and death. The following are examples of homeostasis:

- Regulation of blood glucose levels (involves endocrine, digestive, respiratory, nervous and urinary systems)
- Maintenance of core body temperature (involves muscular, nervous, cardiovascular, integumentary and endocrine systems)
- Regulation of water and mineral concentrations (urinary, digestive, endocrine, and respiratory systems).

An understanding of the role of homeostasis and communication between bodily systems in maintaining normal functions in humans is fundamental to the ability of OHS professionals to provide advice and guidance for the protection of workers from workplace exposures and hazardous systems of work. Knowledge of human physiology should enable the OHS professional to make informed decisions regarding the impacts of chemical, biological, physical, ergonomic and psychosocial issues on workers. Table 1 provides an overview of the biological systems of the human body. (For more information, see for example Scott & Fong, 2009: Sherwood, 2010.) Figure 2 provides an illustration of the interactions between systems and the external environment.

Table 1: Overview of the biological systems of the human body

System	Components	Function
Integumentary	The integumentary system comprises the skin (cutaneous membrane) and its accessary structures, including hair, nails and exocrine glands.	The integumentary system is primarily made up of the largest organ in the body, the skin. The skin protects the body from attack by foreign organisms and prevents the escape of bodily fluids; it helps regulate the body's temperature, provides sensory reception, synthesises vitamin D and hormones. It can also absorb substances. The skin consists of the epidermis (outer layer), the dermis (inner layer containing sensory nerve endings and sweat glands) and the hypodermis (which comprises underlying connective and adipose tissue, and blood vessels.
Cardiovascular /Circulatory	The cardiovascular system consists of the	The heart is divided into two sides. The right side of the heart pumps blood to the pulmonary circuit, where it picks

System	Components	Function
	heart, blood and blood vessels, including arteries, capillaries and veins.	up oxygen from the lungs. The left side of the heart pumps the oxygenated blood throughout the body, where the blood delivers oxygen and nutrients to the tissues. Blood always leaves the heart through arteries (muscular vessels) and returns to the heart through veins (thin-walled vessels). Arteries and veins are connected by capillaries, which transport oxygen and nutrients from blood to the tissues and collect carbon dioxide and waste products from the tissues. Hormones and white blood cells are also transported by the cardiovascular system.
Respiratory	The respiratory system consists of the mouth, nose and nasal cavity, pharynx, larynx, trachea, bronchi, bronchioles and alveoli.	The respiratory system delivers oxygen to the body and removes carbon dioxide through the processes of breathing in air, gas exchange and exhaling air. The human respiratory system is divided into two parts: the upper respiratory tract (nose, pharynx, larynx and trachea) and the lower respiratory tract (bronchi, bronchioles, alveoli and lungs). The upper respiratory tract is like a system of pipes through which the air is funnelled down into the lungs. The bronchioles end in alveoli, which are very small, thin-walled air sacs that contain capillaries, which carry blood that comes through veins from all other parts of the body. The carbon dioxide from the blood is exchanged for the oxygen in the alveoli. The blood containing oxygen then goes to the heart where it is pumped to other parts of the body and the carbon dioxide is exhaled.
Digestive / Gastrointestinal	The gastrointestinal tract or alimentary canal consists of the mouth, pharynx, oesophagus, stomach, small intestine, large intestine, rectum and anus. Accessary structures include the teeth, tongue, salivary glands, liver, gall bladder and pancreas.	The digestive system takes in food, digests it to extract energy and nutrients for the body, and expels the remaining waste. Digestion of food starts in the mouth with chewing and saliva, and continues in the stomach after swallowing and transferal to the stomach via a series of muscular contractions of the oesophagus (peristalsis). The cells in the lining of the stomach secrete a strong acid and enzymes that break down the food. The content of the stomach is then transferred to the small intestine. The small intestine is a long muscular tube consisting of three segments. The pancreas secretes digestive enzymes into the first segment of the small intestine; these enzymes break down protein, fats and carbohydrates. The pancreas also secretes insulin into the blood to metabolise sugar. The liver secretes bile into the small intestine to help digest fat. The liver is responsible for breaking down and detoxifying chemicals; also, it uses nutrients from the intestine to produce chemicals needed by the body. The gallbladder stores, concentrates and releases bile. Bile can also contain metabolites of toxins. The large intestine, or colon, is a long muscular tube that connects the small intestine to the rectum. Waste left over from the digestive process is transferred along the large intestine, and changes from a liquid to a solid ready for elimination from the body via the rectum and anus. The large and small intestine contain microorganisms essential for health. Not only do they have metabolic,

System	Components	Function
		immunological and gut protective functions (Jandhyala et al., 2015) but there is increasing evidence of a gut-brain connection in conditions such as anxiety and depression. (Lach et al., 2018).
Urinary	The urinary system includes two kidneys, two ureters, the bladder, two sphincter muscles and the urethra.	The urinary system works with other organs (lungs, intestine and skin) to remove waste from the body and to keep the chemicals and water in the body balanced. The kidneys are bean-shaped organs about the size of a bar of soap; they remove urea from the blood through tiny filtering units called nephrons. Each nephron consists of a ball formed of small capillaries, called a glomerulus, and a small tube called a renal tubule. Urea, together with water and other waste substances, forms the urine as it passes through the nephrons and down the renal tubules of the kidney. Increased fluid intake generally increases urine production, while increased perspiration and respiration may decrease the amount of fluid excreted through the kidneys. Some medications interfere directly or indirectly with urine production (e.g., diuretics). From the kidneys, urine travels down two thin tubes called ureters to the bladder. The bladder is a hollow muscular organ shaped like a balloon that is held in place in the pelvis by ligaments attached to other organs and the pelvic bones. The bladder stores urine until it is emptied via urination. Circular muscles called sphincters help keep urine from leaking; they close tightly like a rubber band around the opening of the bladder into the urethra, the tube that allows urine to pass outside the body.
Nervous	The nervous system consists of a network of specialised cells called neurons. The nervous system can be divided into two systems: the Central Nervous System (CNS) and the Peripheral Nervous System (PNS). The CNS contains the brain, spinal cord and retina and the PNS contains sensory neurons and ganglia, and nerves that connect them. The nervous system also has specialised cells called glial cells.	The nervous system is the communication pathway for the body, sending messages between different parts via electrical and chemical processes. It coordinates the actions of the body and responds to changes both outside and inside the body. The main functional units of the nervous system are cells called neurons. All neurons have three main parts: dendrites, the cell body and the axon. There are three types of neurons: • sensory neurons, which carry messages from sensory receptors to the CNS • motor neurons, which transport messages from the CNS to muscles or glands • interneurons, which are only in the CNS and connect neuron to neuron. The junction between neurons is called a synapse. Messages travel within the neuron as an electrical signal; at the junctions, the message is transmitted via chemicals called neurotransmitters. The PNS is divided into the somatic nervous system and the autonomic nervous system. The somatic system is made up of nerves that connect to the skin, sensory organs and all skeletal muscles; it is responsible for coordinating the body's voluntary movements and

System	Components	Function
		receiving external stimuli, including hearing, touch and sight. The autonomic nervous system is the largely involuntary control system of the body. It is responsible for such things as heart rate, digestion, respiration rate, salivation, perspiration, pupil diameter, urination and sexual arousal.
Endocrine	The endocrine system is composed of ductless glands and hormones. Organs involved with the endocrine system include: pituitary gland, thyroid gland; parathyroid gland, adrenal glands; pancreas and gonads (testes and ovaries).	The endocrine system is a collection of glands that release chemicals called hormones. The hormones send messages to cells within target organs and are secreted by the ductless glands straight into the bloodstream or interstitial fluid, without storage of the chemical. Hormones can be divided into three groups: steroids, peptides and amines. Endocrine hormones are involved in a range of body processes including growth, repair, sexual reproduction, digestion, homeostasis (constant internal balance) and response to stress.
Lymphatic	The lymphatic system is comprised of the lymphoid organs, lymph nodes, lymph ducts and lymph vessels.	Associated with the immune system, the lymphatic system is a complex network of lymphatic vessels that transports lymph from tissues to the circulatory system. Lymph is a part of the interstitial fluid that lies in the space between body tissues. Lymph returns protein and excess interstitial fluid to the blood, and picks up bacteria and brings them to lymph nodes to be destroyed. It transports fat from the digestive system and white blood cells to and from the lymph nodes into the bones and bone marrow. The lymphatic system maintains fluid levels in the body. It also produces immune cells, such as lymphocytes and monocytes, and is vital for the immune system and detoxification.
Immune	The immune system consists of the spleen, red bone marrow, lymph nodes and thymus.	The immune system is the body's defence mechanism, protecting it against attack by bacteria, parasites, fungi and viruses. The physical barriers of the skin and mucus membranes are the human body's first line of defence against attack. The second line of defence involves certain white blood cells called phagocytes, which engulf foreign bodies and other cells (phagocytosis). Phagocytes include macrophages and neutrophils. Macrophages can be free or located within a specific organ and neutrophils are a type of white blood cell that can become phagocytic. The third and last line of defence – acquired immunity – involves a reaction between the foreign attacker (antigen) and the immune system (antibody); the key cells involved are lymphocytes. There are different types of immune responses with the two main types being humoral (antibody-mediated) and cellular (cell-mediated).
Reproductive	The male reproductive system consists of the spermatozoa, testicles, epididymis, vas deferens, seminal vesicle, prostate gland, urethra, penis and	The function of the human reproductive system is to produce offspring; it involves both the male and female reproductive organs.

System	Components	Function
	scrotum. The female reproductive system consists of the ovum, ovary, fallopian tube, uterus, cervix and vagina.	
Musculoskeletal	The musculoskeletal system includes bones, cartilage, ligaments, muscles, tendons and, in the spine, intervertebral discs.	The main functions of the musculoskeletal system are to provide structural support and to allow the body to move. Other functions of muscles include maintenance of body posture, stabilisation of joints and generation of heat. Other functions of bones include protection of vital organs (e.g. brain, eyes, lungs) and the manufacture of blood cells (haematopoiesis) in the bone marrow inside large bones, and storage deposit of fat and minerals such as calcium and phosphorous. There are three different types of muscles: • Skeletal muscle is attached to bone by tendons and other tissues; it is voluntary, striated muscle controlled by the somatic nervous system. • Smooth (non-striated) muscle is found in the body's internal organs (e.g., intestinal smooth muscle, muscle of the bronchi); it is involuntary muscle controlled by the autonomic nervous system. • Cardiac muscle, only found in the heart, has structural features of both skeletal and smooth muscle; it is involuntary muscle controlled by the autonomic nervous system. Human adults have 206 bones in their skeleton. The 26 vertebra in the spine form the central support for the body and protect the spinal cord. The curved vertebral column allows humans to stand and walk on two feet. The joints between bones permit movement, some allowing a wider range of movement than others (e.g., the ball and socket joint allows a greater range of movement than the pivot joint at the neck). Muscles, bones and joints provide the principal mechanics for movement, all coordinated by the nervous system.

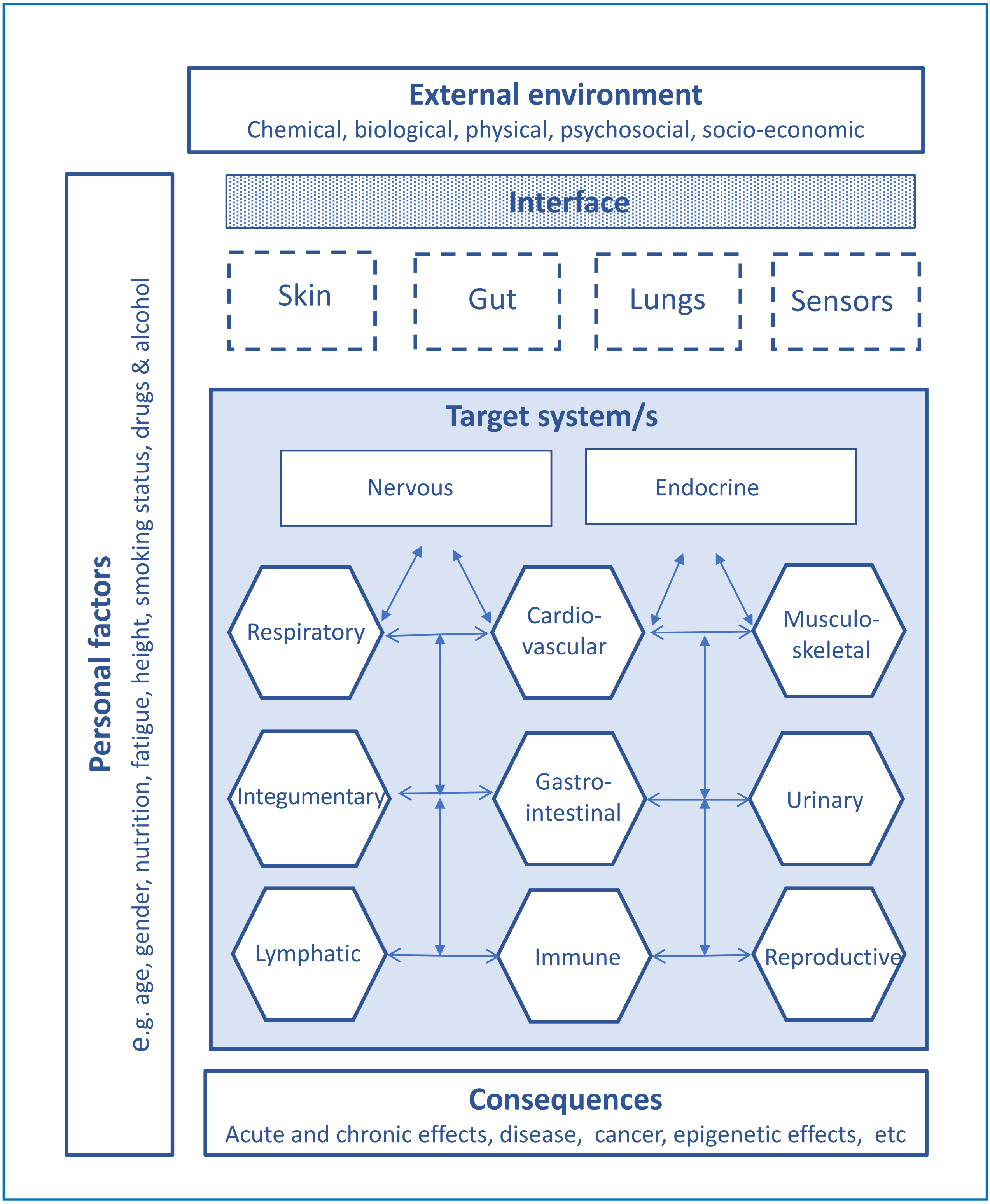

Figure 2: Systems of the body

4 Human variability

In addition to understanding the physiology of the human body, it is important to have an appreciation for human variability. Differences in age, race, sex, body shape and size, and physical, social and intellectual abilities, genetic makeup, etc., play a role in how people interact with and react to each other, the work environment, substances, tools and equipment. Human variability plays an important role in all aspects of occupational health and safety.

While work and work processes are often designed based on the concept of the 'average person,' the reality is that humans are not homogenous. Fields such as anthropometry (measurement of the human body) have access to large data sets indicating the extent of human variability which can be used as a basis for designing workplaces that will accommodate a large percentage of the population. However, in areas such as individual susceptibility to carcinogens or a person's allergic reaction to an exposure in the workplace, there are still many unknowns. There is, however, increasing evidence that certain genes are associated with some occupational diseases and cancers.[3]

Individuals also have variable coping mechanisms to counter psychosocial hazards. Such hazards can elicit stress responses affecting the endocrine, immune and circulatory systems, among others. Adverse effects can exacerbate musculoskeletal disorders resulting from hazardous manual tasks (Oakman, Clune & Stuckey, 2019).[4]

5 Routes of exposure

Foreign substances and microorganisms may be absorbed into the human body via several routes. In the workplace setting, the two most common routes of entry are the respiratory system via inhalation and the integumentary system via dermal absorption. Other routes of exposure include: the eye through splashes of chemical and infectious agents; the digestive system via swallowing; and the circulatory system via an intravenous route. Entry may also occur via puncture or 'injection' such as the entry of *Clostridium tetani* (the bacterium causing tetanus) via puncture with a rusty nail. Understanding the route of exposure is an

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[3] See for example Stojanovic et al., 2017.

[4] For a discussion on the link between psychosocial hazards and musculoskeletal disorders see *OHS BoK* 16 Work-related Musculoskeletal disorders.

important factor in assessing the risk from workplace exposures and determining appropriate control measures.

Once a substance or organism has entered the body, it may exert a local effect at the point of exposure or it may be transported to another part of the body and affect a system distant to the point of exposure (systemic effect). In understanding how the health and safety of individuals can be affected by exposures in the workplace, the OHS professional must examine all possible routes of exposure to substances and organisms and have an understanding of the body's physiological responses (see, for example, Klaasen, 2008).

Human biological systems are involved not only in the entry and distribution of foreign substances, but also in reactions such as their biotransformation, metabolism, excretion and storage. Some substances may need to be metabolised in the body to exert their toxic effect. For any given exposure in the workplace, there may be a number of the body's biological systems involved from the route of entry to the site of damage and the resultant health outcomes.

6 Case studies

The following case studies provide examples of the application of physiological knowledge to situations that a generalist OHS professional could encounter, highlighting the systemic interactions. Figure 2 illustrates the potential interactions of the body systems with the external environment via the interfaces of skin, gastro-intestinal tract, lungs and sensors (eyes, ears, position sensors, etc). The external environmental influence may be a chemical, some form of radiation, an infective agent, a complex exposure to psychological factors, etc. The consequences of such exposures may manifest by activation of one or more of the body's physiological systems with an outcome that may restore homeostasis or lead to acute or long-term ill health and disease or even death. The following scenarios provide examples of how the body's physiological systems may interact when the body is subjected to some form of environmental/occupational insult.

6.1 Scenario 1: Pesticides and routes of exposure

Exposure to some substances in the workplace can have adverse effects on the nervous system (neurotoxicity); poisonous chemicals – neurotoxicants – are used in a variety of occupations. Examples include solvents (e.g., carbon disulfide), pesticides (e.g., organophosphates, pyrethroids, organochlorines, formamidines), metals and organometals (e.g., lead, mercury, trimethyltin) (Fiedler, 2010). This scenario focuses on an example neurotoxin as a basis for discussion of routes of exposure and toxic effects on the various systems of the human body.

Sarah, an occupational health and safety professional with a background in the Life Sciences, recently started work as the OHS Coordinator for an international pesticide formulation company at one of their Australian formulation plants. Asked to review the plant's occupational health monitoring program, she has started by focusing on one of the main groups of pesticides the company manufactures – organophosphate (OP) pesticides.

Currently, all 60 staff members at the site routinely undergo health monitoring twice yearly, which includes:

- *A blood sample taken to obtain an estimate of the red cell and plasma cholinesterase activity towards the end of a working day on which OPs have been used*
- *A physical examination and health advice from the company's occupational physician.*

Background reading
Being new to the company and unfamiliar with current thinking on organophosphate pesticides (OPs) exposure, Sarah starts by doing some background reading. She finds that OPs are the most widely used insecticides in Australia: "About 5000 tonnes of active ingredients from this group, which comprises 30 identifiably distinct chemicals, have been used annually" (Radcliffe, 2002). OPs are most often used as pesticides on crops and as veterinary medicine and are also used for domestic and public health applications. While OPs are nerve poisons that kill target pests, usually insects, they also can act on the nervous systems of exposed humans. Exposure to OPs can cause both acute (immediate) and chronic (longer-term) health effects, which are related to the interaction of the chemicals with enzymes in the nervous system. Toxicity of organophosphates may vary between being only slightly hazardous, to being extremely hazardous, when only a very small quantity of pesticide can be fatal to humans.

Observations
Sarah's second step is to observe the formulation workers the next time they do a production run of an OP pesticide. She watches the whole process of formulation, that is mixing the active and inert ingredients into a final packaged product, and identifies the potential for worker exposure to the active ingredient (in this case a powder) via inhalation and dermal absorption. She notes the importance of current engineering control measures and compliance with the company's procedures for use of personal protective equipment and good personal hygiene practices. Because the workers are handling pure OP in its raw unformulated state, Sarah also recognises the potential for high levels of exposure.

Discussion with the company's occupational physician
After background reading and observing the work practices, Sarah makes an appointment to meet the company's occupational physician to discuss the workers' exposure to OPs and the health monitoring program.

Sarah and the physician begin by discussing how OPs typically enter the body. Although OPs can be inhaled, particularly if dusts, mists or vapours are involved Sarah's company requires the use of respiratory protection and employs fit-testing for all workers working on or near OP formulation. Thus dermal absorption is considered the most common route of entry but OPs may also the enter the body via the mucus membranes and eyes. Because there are no local effects at the site of entry, dermal absorption will often go unnoticed until systemic symptoms develop (Broadley, Banks, Collinge & Middleton, 2000). Sarah recalls noting during her observations that the formulators had rolled the sleeves up on their overalls and had powder on their forearms.

Sarah and the physician review the pharmacology and toxicology of OPs. When OPs are absorbed, they react with (inhibit) cholinesterase enzymes in the body. The two cholinesterase enzymes are acetylcholinesterase, which is found in nervous tissue, muscle and red blood cells and pseudocholinesterase which is found mainly in the blood plasma, liver and pancreas. Acetylcholinesterase metabolises acetylcholine, which is a neurotransmitter responsible for activating muscles. Acetylcholinesterase rapidly removes acetylcholine from nerve synapses once a nerve impulse has been transmitted. In OP pesticide poisoning, the OP reduces the available acetylcholinesterase at nerve synapses resulting in over-stimulation. Symptoms of poisoning usually do not occur until enzyme activity is reduced to 60-25% of a person's baseline.

The physician explains that acute effects occur rapidly after exposure. In short-circuiting the somatic and autonomic nervous systems, the acute effects can cause malfunctions in many of the body's biological systems. These effects may manifest as symptoms of the respiratory system (e.g., increased mucus secretion, bronchoconstriction), the cardiovascular system (e.g., bradycardia, tachycardia), the digestive system (e.g., abdominal cramps, nausea, vomiting), the urinary system (e.g., loss of bladder control), and effects on the central nervous system can manifest in symptoms such as headache, anxiety, restlessness, confusion, slurred speech and convulsions, as well as affecting the eye's ability to focus. The wide range of symptoms of acute poisoning is well documented (Klaassen, 2008; LaDou, 2004). Acute intoxication can also lead to death; however, with appropriate emergency treatment, death is less likely.

Like other toxic exposures in the workplace, the type and extent of ill-health effects that result from exposure to an OP pesticide are influenced by six factors:

1. **Toxicity**… The inherent degree of toxicity of the particular pesticide
2. **Exposure dose**…the amount and concentration of the toxic agent in contact with the point(s) of uptake into the body and duration of the contact.
3. **Absorbed dose** …the amount and time over which the agent is taken up by the body.
4. **Target dose**…the concentration and time for which the target site(s) are in contact with the agent [in this case the nervous system tissue].
5. **Target effect**…the response of the target to the target dose of the toxic agent.
6. **Ill-health**…the final effect of the exposure on the well-being of the exposed person. (Karalliedde, Edwards & Marrs, 2003, p. 2)

There are two main types of chronic health effects:

- After-effects from one or more acute poisoning incidents, such as OP-induced delayed polyneuropathy (OPIDP), which is an uncommon sequelae to acute poisoning, and
- Effects that result from long-term, low-level exposure with no acute poisoning incident, such as OP-induced neuropsychiatric disorder (COPIND) (Davies, Ahmed & Freer, 1999).

Generally, effects are neuropsychological and neurological in nature. However, the evidence for chronic effects from low-level, long-term exposures with no acute poisoning is still being debated in the literature (see, for example, CDC, 2010; Ross, McManus, Harrison & Mason, 2013). Considering the uncertainty of possible long-term health effects from chronic low-level exposure, Sarah believes it is important to ensure that the levels of exposure are kept to as low as reasonably practicable (ALARP).

In terms of health monitoring for OP pesticide exposure, the physician confirms that the company is following a program that complies with legislative requirements; this involves collection of the person's demographic, occupational and medical history, including pattern of OP use, a physical examination, and collecting and analysing a blood sample for estimation of red cell and plasma cholinesterase activity levels, which are compared to the worker's baseline levels. Sarah confirms that baseline estimates of cholinesterase are determined in new employees before they are exposed to OPs. As there are often delays between exposure and depression of cholinesterase activity, she discusses with the occupational physician the possible use of the urinary OP metabolites test as a more immediate and sensitive indicator of OP absorption (Johnstone, Capra & Newman, 2007 and SWA, 2020).

OHS professional's response

Sarah now understands the complexity of the body's response to OP exposure and the need to be proactive in developing controls to minimise worker exposure to OPs and to have a robust monitoring system to assess worker exposure. Sarah returns to the workplace to further investigate the company's health monitoring program. As part of this process, she secures an agreement from the company to have the occupational physician use the urinary OP metabolites test, which is an indicator of exposure, as well as cholinesterase activity, which is a measure of the biological effect, in the monitoring of OPs. While beginning discussions with Operations on engineering controls she also implements a program to monitor compliance with PPE requirements including for full body covering.

6.2 Scenario 2: Dermal exposure to cleaning agents: Local and systemic effects

Diseases of the integumentary system (skin diseases) are amongst the most frequently occurring occupational diseases (Pal, deWilde, van Beurden, Coenraads & Brynzrrl, 2009). However, because workers with occupational skin diseases generally do not require time off work, the Australian workers compensation statistics may not portray an accurate picture of the true prevalence of this disease type; in fact diseases of the integumentary system account for only 0.4% of all compensation claims (SWA, 2021). Based on the UK (EPIDERM) program, an occupational skin disease surveillance scheme was conducted from 2001 to 2005 in the Netherland (Pal et al., 2009). This scheme gathered information about occupational skin diseases, including incidence rates, causal agents and potential occupational groups at risk. The results indicated an incidence rate of 0.8/1000 workers, which correlates with data from other European countries and the USA (Pal, et al., 2009). Occupations most at risk include health and social care workers, hairdressers/barbers, beauticians, manufacturers of chemicals and chemical products, metalworkers, mechanics and cleaners (Turner, et el., 2007, Pal et al., 2009).

The following scenario is presented as a basis for discussion of the integumentary system and the potential impact of damage to the skin and related structures.

Since completing his apprenticeship as a diesel fitter, Bob has worked in his trade. Currently, he is employed by a company that contracts to service heavy earthmoving equipment. His work involves contact with grease and solvents, and he often has to rely on strong soaps and solvents to clean his hands. Three months ago, the workplace introduced a new skin cleanser, and since that time he has developed an itchy red rash on his hands, with some splitting and cracking of the skin.

After conducting a preliminary investigation into Bob's reported health concerns, the generalist OHS professional decides to contact the company's occupational health physician for advice regarding Bob's condition.

The occupational health physician's response

The physician explains the structure of the integumentary system and how it can be damaged. He explains that while in this case the damage is likely to be physical defatting of the skin, an allergic response or a combination of both, is also possible.

Skin is comprised of three main layers (epidermis, dermis and subcutaneous). The outer layer, the epidermis, contains no blood vessels. The underlying dermis contains mechanoreceptors (receptors for sensing touch), which form part of the somatosensory system, as well as hair follicles, sweat and sebaceous glands, lymph and blood vessels. The dermis is attached to underlying bone and muscle via subcutaneous loose connective tissue (the hypodermis), which includes adipose tissue (fat).

The skin's protective barrier is reliant on an intact cellular layer, together with the excretion of natural oils from the sebaceous glands. Activities that remove the skin's natural oils or fats (e.g., exposure to solvents or excessive hand washing) may deplete the natural oils, and leave the skin more vulnerable to other irritants or allergens. Broken skin allows substances to reach deeper into the skin layers. Occupational dermatitis is one of the most common occupational skin disorders (see, for example, Winder, 2004). There are two types of occupational contact dermatitis:

- Irritant contact dermatitis (most prevalent form)
- Allergic contact dermatitis.

Contact dermatitis (also called contact eczema) refers to changes in the skin, usually accompanied by inflammation, from direct skin contact with physical or chemical agents (Winder, 2004). The skin inflammation is caused either by contact with an irritant, which damages the skin, or a sensitiser, which causes an allergic reaction. With irritant contact dermatitis, the substance may act immediately (e.g., strong acids or bases) or over a longer time period (e.g., detergents or hand cleaners). Irritant contact dermatitis may result from multiple cumulative exposures to often more than one potential skin irritant, rather than a single substance (Winder, 2004).

The requirement to repeatedly wash the hands with strong soaps or worse, solvents, will remove natural oils from the skin, and reduce its effectiveness as a barrier. Repeated hand washing on its own or even wet work tasks (resulting in wet hands for more than 2 hours per shift) may cause skin irritation, as well as increasing the risk/likelihood of response to other agents. The new cleanser may be responsible for the onset of symptoms simply by being a more powerful agent that has defatted the skin, or it might contain a component to which Bob has developed an allergy. Or, indeed, it may be a red herring; another substance with the potential to irritate the skin or cause an allergic response may have been introduced into the workplace. Furthermore, due to human variability there are some individuals in the workplace who may have a genetic predisposition to developing dermatitis (called atopy). The OHS professional should encourage Bob to go to his GP and be referred to a dermatologist.

The occupational physician explains the difference between physical damage to the integumentary system by an irritant and an allergic response by referring to a patient who had worked as a registered nurse for many years before specialising in theatre nursing. For six months she struggled with redness, itching, and thickening and cracking of the skin. Whilst aware of the possible contribution of hand washing to her symptoms, she had no choice whilst working in theatre but to continue to wash her hands. She was referred to a dermatologist, and patch testing confirmed that she had developed an allergic response to latex, which is used in surgical gloves (allergic contact dermatitis – type IV hypersensitivity). As explained by the Occupational Dermatology Research and Education Centre:

> Allergic contact dermatitis is a delayed type of allergy. Allergy is very individual (i.e. a person may be allergic to something that another person can use with no problems). It can occur at any time even if you have been using a product for many years or just a few weeks. With dermatitis, the rash appears 8 to 24 hours after contact and lasts for several days, and sometimes more. If the skin is already damaged, such as being dry and cracked, the risk of becoming allergic to something is much higher. Once an allergy to something has developed, it is lifelong and even the smallest amount of contact will cause the rash to appear again. (ODREC, 2010)

The primary allergens involved in allergic contact dermatitis from latex glove use are residues of accelerators (chemicals used to speed up the manufacturing process of rubber) and antioxidants (added to protect the glove from drying and cracking due to environmental oxygen or ozone exposure) left from the original manufacturing process. The consequences of skin exposure to these accelerators are not only in the skin but also reactions such as rhinitis and asthma may occur as a result of interactions between the immune and respiratory systems. In extreme cases anaphylactic shock can occur which involves the immune, respiratory, cardiovascular, and digestive systems and can be fatal, if not immediately treated (Mustafa, 2018).

OHS professional's response
Having spoken to the occupational physician, the OHS professional takes their advice and advises Bob to visit his GP and be referred to a dermatologist. With the hierarchy of control in mind[5] the OHS professional also obtains a copy of the Safety Data Sheet for the hand cleanser and investigates alternative hand cleansers that are less likely to cause allergic dermatitis, consults with Bob and the other diesel fitters about the potential for gloves to reduce the frequency of chemical cleansing of hands. The OHS professional also consults with the occupational physician on the use barrier cream to reduce the effect of the hand cleanser on the skin.

6.3 Scenario 3: Infectious agents and interactions with multiple systems

Infectious agents that are responsible for disease may be classified as:

- Pathogens – viruses, bacteria, fungi and parasites [protozoa, helminths (worms) and ectoparasites (ticks and mosquitoes)]
- Zoonoses – infections transmitted to humans from animals and include bacteria, viruses and parasites such as tapeworms. (Jones, 2021)

Viral infection can have widespread effects across communities. The COVID-19 pandemic caused by the novel corona virus (SARS-CoV-2) will be long remembered for its community and workplace transmission, as well as its devastating health and economic effects. SARS-CoV-2 infections have also demonstrated that infection from a virus or other infective agent can have both acute (e.g., severe acute respiratory syndrome, SARES) and long term effects (e.g., 'Long Covid') on the biological systems of the body. (Perrin, Riste, Hann at al., 2020). There are also suggestions that other long-term conditions such as chronic fatigue syndrome (CFS) are linked to viral infections but there is no conclusive evidence to confirm that any particular infective agent is responsible for CFS (Rasa S, Nora-Krukle Z, Henning N, et al., 2018)). Individuals who are recovering from Q fever may also experience fatigue for an extended period.

Not only can the aftermath of infections have a long term impact on the biological systems of the body, but they may be passed on via the reproductive system to have effects in the next

[5] See *OHS BoK* 34.1 Prevention and Intervention.

generation (Elkady, Sinha & Hassan, 2019). Typical examples of such transmissions are viral infections such as zika (Hajra, Bandyopadhyay, Heise, et al., 2017) and rubella (Forrest, Turnbull, Sholler, et al., 2002) and bacterial infections such as Q fever (Marks & Olenski, 2019).

In the following scenario, the infective agent is the protozoan *Toxoplasma gondii* that is responsible for the disease toxoplasmosis, which can have very serious implications if contracted in pregnancy, especially in early pregnancy or just prior to conception (McAuley, 2014). While historically, female workers in animal industries and veterinary practice were at risk, occupational acquisition of toxoplasmosis and other zoonotic diseases such as leptospirosis is now relatively rare in Australia but cases still occur from domestic exposures.

The following scenario addresses the prospect of an Australian worker acquiring a serious illness as a result of their work in an overseas country, as part of their employment. Many Australians take short to medium term overseas postings as part of their Australian employment, and as a result, encounter exposure to both health and safety risks that are different to those expected in Australia. While some of these risks are foreseeable and can be managed others are not; thus holistic risk management is required prior to departure from Australia.

Tracy is a 32 year old employee of AusAgriAdvisory Services (AAAS) a small but specialised agronomy company based in regional NSW. She has qualifications in agronomy and education. The principal of the company is Steve who also has qualifications and over 30 years' experience in agronomy.

Steve successfully competed for an international aid project to assess proposed crop improvement measures for a revitalised groundnut production in a southern African country. The project's brief was to evaluate the country's Ministry of Agriculture's crop improvement plans, modify these, if necessary, in consultation with the Ministry and to develop an extension program for implementation by the groundnut industry, which is predominantly made up of small holding farmers. The project was divided into two phases, an initial in-country scoping and evaluation exercise of two weeks, to be followed by a later in-country phase of two to three months for delivery of the extension program.

Steve asked Tracy to accompany him for the first phase to work with the Ministry to develop the extension program. Tracy's major involvement would be working with Ministry personnel in the capital city to develop an extension program while Steve would visit a number of the small holding groundnut farms in several regions of the country. While Steve had carried out a number of projects in developing countries, it would be Tracey's first experience in a developing country. Steve was well aware of the health risks involved in working in developing countries and checked the DFAT website (https://www.smartraveller.gov.au/) before arranging for visits to his GP for Tracey and himself to discuss vaccinations and medication that might be needed. The GP recommended that Steve and Tracy should take malaria prophylaxis and have current vaccination for hepatitis A and B, typhoid fever and MMR (Measles, Mumps and Rubella). The GP also suggested that Steve should have yellow fever vaccination as he would be in rural areas where yellow fever may be endemic.

The first phase of the in-country work went well with Steve visiting many provincial groundnut farms and Tracy working closely with the Ministry staff on the extension plans. On their last *day in country before travelling back to Australia Tracy and Steve were invited to visit a pig farm which was a new enterprise about 40km from the capital. Although Steve and Tracy are agronomists, the in-country host wanted to showcase some of their recent agricultural achievements. The field day at the pig farm was an interesting experience topped off with a BBQ of fresh pork and an appreciation of a different aspect of African primary production.*

About 2 weeks after returning to Australia, Tracy began to feel quite unwell with a range of symptoms including fever, muscle aches and pains, headaches, nausea and menstrual changes. After taking a thorough medical history, in which her GP elicited her history of travel, the doctor found some swollen lymph glands, and also arranged a rapid in-surgery pregnancy test which established that Tracy was pregnant, having conceived shortly before she left for Africa. This latter finding was welcomed as Tracey and her partner had been trying to conceive for some time. Unfortunately, the symptoms other than nausea and menstrual changes are not usually related to pregnancy and these symptoms greatly concerned the GP, especially for a woman early in the first trimester of pregnancy. The GP ordered an extensive battery of pathology tests for unexplained fever that resulted in a diagnosis of toxoplasmosis. Once the diagnosis had been made the GP began a treatment regimen as recommended in the current literature (Saso, Bamford, Grewal, et al., 2020).

The *Toxoplasma* parasite can persist for long periods of time in the bodies of humans and other animals, possibly even for a lifetime. Of those who are infected however, very few have symptoms because a healthy person's immune system usually keeps the parasite from causing illness. However, the consequence of toxoplasmosis in pregnant women can be quite severe, especially if the exposure to the organism is early in the pregnancy. The organism can be transported across the placenta and affect the developing foetus. Mother-to-child transmission rates have been reported to range from 11.3% (Ricci et al., 2003) to 18.5% (Varella et al., 2009). The risk of transmission increases with gestational age (from 5% at 12 weeks to 80% just before birth) (Dunn et al., 1999). However, babies infected early in pregnancy have a greater risk of congenital anomalies (Di Mario et al., 2009). Most infants who are infected while still in the womb have no symptoms at birth, but they may develop symptoms later in life. A small percentage of infected newborns have serious eye or brain damage at birth. Absence of symptoms in the newborn, unfortunately is not indicative of later development of signs and symptoms of disease that may include seizures, hydrocephaly learning disabilities, motor disabilities and hearing and eyesight impairment (Saso, Bamford, Grewal, et al., 2020).

Tracy was most likely infected with *Toxoplasma gondii* from the BBQ pork she ate on her last day in Southern Africa due to the meat being undercooked and/or cut with a contaminated knife. Toxoplasmosis infection results from a variety of possible sources including eating undercooked meat, drinking contaminated water or from contact with animal faeces especially cat faeces.

Tracy was unfortunately in an environment that exposed her to a known infective agent at a critical phase of her life. This scenario is reminiscent of the Swiss cheese model frequently used in safety science except in Tracy's case the consequences occur over a much longer time frame and affect not only her but also her child. The health and environment factors involved include her working for a short time in another country away from her normal environment, unexpected consumption of the infective agent at a single event and her pregnancy. Fortunately, after diagnosis and treatment, Tracy had a normal pregnancy and delivery. However, with toxoplasmosis even after successful treatment during pregnancy, there remains a very low probability that her child may in the future develop symptoms associated with the in-utero infection.

6.4 Scenario 4: Chronic psychosocial exposure

The body has a mechanism to allow individuals to respond to threats in the environment with increased arousal or alertness. This so-called stress response of increased arousal or alertness is facilitated by the hypothalamus in response to external factors. This activates the sensory nervous system and the hypothalamus-pituitary adrenal axis goes into action. This results in increased cortisol available in the body that helps to boost sugar in the bloodstream, helps the brain access this sugar, regulates metabolism and reduces inflammation, ready to respond to a real or perceived threat. While this response may support survival in an acute emergency, in modern day life we may be subject to chronic stressors at which point this mechanism may become dysfunctional, resulting in negative health impacts. Associations have been identified between chronic stress at work, and coronary heart disease, Type II diabetes, immunosuppression and reduced ability to fight infection (Kumari et al., 2004; Stansfield et al., 2002, Dar et al., 2019). The stress hormone, cortisol, has a different action on different cells and has also been associated with increased insulin resistance, central redistribution of body fat, increased blood pressure and impaired immune response. Simultaneously catecholamines, adrenaline and nor-adrenalin are produced by the adrenal glands and long-term exposure can lead to increased insulin resistance, increased heart rate and increased blood pressure.

The impact of continued exposure to stress or psychosocial risks is that this process is constant and does not give time for the body to recover from stress exposure. The individual ends up in a constant state of high alert with the associated chemical increases and body responses.

Jane is a 45-year-old home care worker who has been taking on a variety of shifts over the last 20 years while having and bringing up her two children. The work, up to now, has enabled her to manage her shifts, childcare and social activities including a weekly walking group with friends. For the last year she has become increasingly frustrated with her job as the shifts keep changing and being moved around and there appears to be no continuity of care having a different group of clients every week. While Jane accepts the emotional demands of the job role, the precarious nature of a zero hours contract and shifts changed with little notice is having a negative effect on her finances and her ability to socialise outside of work.

Jane has visited her GP as she has also been gaining weight and getting headaches, occasional nose bleeds and a pounding feeling in her head. The GP identifies that her blood pressure is raised and asks her about the weight gain and what she attributes that to. During *the consultation Jane identifies that due to short notice of shift times, she is not able to join her friends walking on a weekly basis and as she has been feeling fatigued, has not been taking any other exercise. Jane also thinks she has been 'stress eating' as well as having more regular glasses of wine in the evening.*

Before prescribing any hypertension medicine, the GP wants to monitor Jane's blood pressure over a week but at the same time encourages her to take some exercise, think about the food she is eating and to discuss her current experience of work with her line manager and others at the workplace including those tasked with occupational health and safety.

Line Manager Response
Jane's line manager is a sympathetic listener but also has ten other people to manage. However, she agreed that there was an issue of unpredictability of shifts and lack of communication between supervisors and carers in relation to care plans and hand-over between carers.

She also agreed that changes were required to workforce planning to try to reduce short-term need issues and to ensure a fair number of shifts for everyone and to balance workload. This was achieved by a group discussion with all members of the team and the sharing of views also gave the team an opportunity to get to know each other and to think about how they could support each other day-to-day both peer-to-peer and manager-to-carer. This also helped to improve communication between the line manager and the carers and among the carers

OHS professional's response
While risk assessments for the carers had been carried out these had been focused on the physical aspects of work as a carer. It was appreciated that carers were exposed to other hazards including lone working, working with unpredictable clients, shift work, working in a variety of different homes and exposure to psychosocial risks.

Group meetings continued with the line manager and the OHS professional discussed the hazards with the carer team. The shared identification of hazards allowed the OHS professional to discuss potential solutions with the group of carers.

Some issues taken forward were:

- Physical workplace issues – ensuring all carers have the skills to make a risk assessment on entry to any new residence both in relation to physical work and personal safety
- Psychosocial hazards – as a group, identifying hazards and developing solutions such as support networks. Thinking about the importance of personal health and health promotion
- Communication and personal safety improved through use of mobile phone technology to maintain contact during shifts, to check-in with each other during shifts, and the use of an update App for any change to care plans
- Shift work and shift allocation – working with the line manager and human resources to find a solution to ensure equity in the number, timing and location of shifts
- New recruits – proper induction, training and buddying system with a more experienced carer for all new staff.

In a scenario such as this, the OHS professional may not be called upon, or have an opportunity to intervene until some crisis point has been reached which may manifest as increased sickness absence, behaviour or performance problems at work, or a workers compensation claim for 'stress'. The treating doctor's role may be limited to providing certificates, and may have little opportunity to intervene in the 'real' cause of the problem unless requested to do so by a workers compensation insurer or case manager. Where the OHS professional is involved in this process they can become a valuable bridge between the workplace, the injured worker, and other involved parties.

7 Implications for OHS practice

The generalist OHS professional requires a working knowledge of the physiology of the human body[6] particularly from a biological systems perspective. In anticipating, preventing and mitigating the impact of hazardous work exposures they need to recognise that the various physiological systems interact such that the overall impact on the workers' health may by different to the impact on the individual physiological systems.

Providing accurate and appropriate advice on the impact of hazards and the likely health effects of changes in the workplace requires consideration of the physiology of the human as a system so that all possible responses or health effects are identified. This may entail seeking specialist advice from, for example, an occupational hygienist, an occupational physician, an ergonomist or a toxicologist. Indeed, generalist OHS professionals should expect to be continually challenged to recognise potential new health hazards or old hazards in a new form.

8 Summary

Humans are complex organisms. An understanding of human physiology and, in particular, the biological systems and their interactions, is vital to the generalist OHS professional's competent anticipation, recognition, evaluation and control of workplace exposures that may be hazardous to human health and safety. This chapter briefly discussed some important historical milestones that have impacted our current understanding of the effects of workplace issues on human health, presented an overview of the biological systems and applied knowledge of these systems to four OHS case studies emphasising the biological interactions.

[6] See also *OHS BoK* 14 Foundation Science.

References

Blanc, P. D. (2007). *How everyday products make people sick: Toxins at home and in the workplace.* Berkeley, CA: University of California Press.

Broadley, R., Banks, A., Collinge, M., & Middleton, K. (2000). *Pesticide application manual* (3rd ed.). Queensland Department of Primary Industries.

Carter, T. (2004). British occupational hygiene practice 1720–1920. *Annals of Occupational Hygiene*, *48*(4), 299–307.

CDC (Centers for Disease Control and Prevention). (2010). *National Report on Human Exposure to Environmental Chemicals* (Chemical information: Organophosphate insecticides). Retrieved from http://www.cdc.gov/exposurereport/data_tables/OP-DPM_ChemicalInformation.html

Dar, T., Radfar, A., Abohashem, S., Pitman, R.K., Tawakol, A. and Osborne, M.T., 2019. Psychosocial stress and cardiovascular disease. Current treatment options in cardiovascular medicine, 21(5), p.23.

Davies, D. R., Ahmed, G. M., & Freer, T. (1999). Chronic organophosphate induced neuropsychiatric disorder (COPIND): Results of two postal questionnaire surveys. *Journal of Nutritional & Environmental Medicine*, *9*(2), 123–134.

Di Mario S, Basevi V, Gagliotti C et al (2009) Prenatal education for congenital toxoplasmosis. *Cochrane Database Syst Rev* 2009, Issue 1. Art. No.: CD006171. DOI: 10.1002/14651858.CD006171.pub2.

Doll, R. (1975). Pott and the path to prevention. *Arch Geschwulstforsch*, 45(6), 521–531.

Dunn D, Wallon M, Peyron F et al (1999) Mother-to-child transmission of toxoplasmosis: risk estimates for clinical counselling. Lancet 353(9167): 1829–33.

Elkady A, Sinha S & Hassan S. Eds. (2019) Infections in Pregnancy: An Evidence-Based Approach. Cambridge University Press.

Farrington, B. (1947). *Head and hand in ancient Greece: Four studies in the social relations of thought.* London: Watts & Co.

Fiedler, N. (2010). Human nervous system and behavioral toxicology. In C. A. McQueen (Ed.), *Comprehensive toxicology* (2nd ed.) (pp. 383–398). Oxford: Elsevier.

Forrest JM, Turnbull FM, Sholler GF, et al (2002). Gregg's congenital rubella patients 60 years later. *Medical Journal of Australia.* 177 (11-12).

Gochfeld, M. M. (2005). Chronologic history of occupational medicine. *Journal of Occupational & Environmental Medicine, 47*(2), 96–114.

Hajra A, Bandyopadhyay D, Heise LR, et al (2017) Zika and pregnancy: A comprehensive review. *Am J Reprod Immunology 77.*

Hoy RF, et al. Artificial stone-associated silicosis: a rapidly emerging occupational lung disease. *Occup Environ Med* 2018;75:3–5. doi:10.1136/oemed-2017-104428

Jandhyala, S. M., Talukdar, R., […], Reddy, D. N. (2015). Role of normal gut microbiota. *World Journal of Gastroenterology*; 21(29):8787-8803. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4528021/.

Johnstone, K., Capra, M., & Newman, B. (2007). *Organophosphate pesticide exposure in agricultural workers: Human exposure and risk assessment.* Barton, ACT: Rural Industries Research and Development Corporation.

Jones, A. (2021). Biological Hazards. In *The Core Body of Knowledge for Generalist OHS Professionals*. 2nd Ed. Tullamarine, VIC: Australian Institute of Health and Safety. Retrieved from https://www.ohsbok.org.au/chapter-18-biological-hazards/.

Karalliedde, L. D., Edwards, P., & Marrs, T. C. (2003). Variables influencing the toxic response to organophosphates in humans. *Food & Chemical Toxicology, 41*(1), 1–13.

Klaassen, C. D. (Ed.). (2008). *Casarett and Doull's Toxicology: The basic science of poisons* (7th ed.). United States of America, McGraw-Hill.

Kumari M, Head J, Marmot M. (2004). Prospective study of social and other risk factors for incidence of type 2 diabetes in the Whitehall II study. Arch Intern Med. 2004;164(17):1873–80.

LaDou, J. (2004). *Current occupational & environmental medicine* (3rd ed.). New York, NY: Lange Medical Books/McGraw-Hill.

Lach, G., Schellekens, H., Dinan, T. G., & Cryan, J. E. (2018). Anxiety, depression, and the microbiome: A role for gut peptides. *Neurotherapeutics*; 15:36-59.

Luke, D. A., & Stamatakis, K.A., (2012). Systems science methods in public health: Dynamics, networks, and agents. *Annual review of public health*, 33:357-376.

Marks S, and Olenski M (2019) Q Fever in the First Trimester: A case study Report from Northern Rural New South Wales. *Trop Med Infect Dis 90*.

McAuley JB, (2014). Congenital Toxoplasmosis. *J Pediatric Infect. Dis Soc. 3 (1).*

Meade, B. J., Weissman, D. N., & Beezhold, D. H. (2002). Latex allergy: Past and present. *International Immunopharmacology, 2*(2–3), 225–238.

Merriam-Webster. (2012). MedlinePlus Medical Dictionary. Retrieved January 4, 2012, from http://www.merriam-webster.com/medlineplus/system

Mustafa, S.S., (2018). Anaphylaxis. *Medscape*. Retrieved July 7, 2021, from https://emedicine.medscape.com/article/135065-overview#a2

Oakman, J., Clune, S. & Stuckey, R. (2019). Work-related Musculoskeletal Disorders in Australia. Safe Work Australia. Retrieved from https://www.safeworkaustralia.gov.au/doc/work-related-musculoskeletal-disorders-australia.

ODREC (Occupational Dermatology Research and Education Centre). (2010). Contact dermatitis. Retrieved January 4, 2012, from http://www.occderm.asn.au/contact-dermatitis.html

Pal, T. M., de Wilde, N.s., van Beurden, M.M., Coenraads, P.J., & Brynzeel, D.P. (2009). Notification of occupational skin diseases by dermatologists in The Netherlands. *Occupational Medicine 59*(1), 38-43.

Perrin R, Riste L, Hann M, et al. (2020). Into the looking glass: Post-viral syndrome post COVID-19. *Med Hypotheses 144*

Pope, M. H. (2004). Ramazzini: The father of occupational medicine. *Spine*, *29*(20), 2335–2338.

Radcliffe, J. C. (2002). *Pesticide Use in Australia: A Review Undertaken by the Australian Academy of Technological Sciences and Engineering*. Parkville, VIC: Australian Academy of Technological Sciences.

Ramazzini, B. (1940). *De morbis artificum diatriba.* [The Latin text of 1713, rev. with translation and notes by W. C. Wright.] Chicago, IL: University of Chicago Press.

Rasa S, Nora-Krukle Z, Henning N, et al (2018). Chronic viral infections in myalgic encephalomyelitis/chronic fatigue syndrome (ME/CFS). J*. Translation Medicine, 16 (268)*

Ricci M, Pentimalli H, Thaller R et al (2003) Screening and prevention of congenital toxoplasmosis: an effectiveness study in a population with a high infection rate. *J Matern-Fetal Neonat Med,* 14(6): 398–403.

Ross, S.M., McManus, I. C., Harrison, V., & Mason, O. (2013). Neurobehavioral problems following low-level exposure to organophosphate pesticides: a systematic and meta-analytic review. *Critical Reviews in Toxicology,* 43(1): 21-44.

SWA (Safe Work Australia). (2020). *Health Monitoring* Guide *for Organophosphate Pesticide.* Retrieved from https://www.safeworkaustralia.gov.au/doc/organophosphate-pesticides-health-monitoring

SWA (Safe Work Australia). (2021). *Australian Workers' Compensation Statistics 2018–19*. Retrieved from https://www.safeworkaustralia.gov.au/doc/australian-workers-compensation-statistics-2018-19

Salmon, P., Read, G., & Hulme, A. (2021) Systems. In *The Core Body of Knowledge for Generalist OHS Professionals*. 2nd Ed. Tullamarine, VIC: Australian Institute of Health and Safety. (in publication).

Saso A, Bamford A, Grewal K, et al (2020) Fifteen-minute consultation: Management of infant born to a mother with toxoplasmosis in pregnancy. *Arch. Dis. Child Edu. Prac. 105*

Scott, A. S., & Fong, E. (2009). *Body structures & functions* (11th ed.). Clifton Park, NY: Delmar Cengage Learning.

Sherman AC, Mehta A, Dickert NW, Anderson EJ &Rouphael N. (2019). The Future of Flu: A Review of the Human Challenge Model Systems Biology for Advancement of Influenza Vaccinology. *Front. Cell. Infect. Microbiol17 April 2019.* https://doi.org/10.3389/fcimb.2019.00107

Sherwood, L. (2010). *Human physiology: From cells to systems* (7th ed.). Belmont, CA: Brooks/Cole.

Škrobonja, A., & Kontošić, I. (2002). Bernardino Ramazzini's *De morbis artificum diatribe* or three hundred years from the beginning of modern occupational medicine. *Arhiv za Higijenu Rada i Toksikologiju* (*Archives of Hygiene & Toxicology*), *53*(1), 31–36.

Slavec, Z. Z. (1998). Occupational medicine in Idria mercury mine in 18th century. *Vesalius*, *4*(2), 51–59.

Smith. D. R. (2010). *Creating environmental and occupational health.* Sydney, NSW: Sydney University Press.

Stansfeld SA, Fuhrer R, Shipley MJ, Marmot MG. Psychological distress as a risk factor for coronary heart disease in the Whitehall II study. Int J Epidemiol. 2002;31(1):248–55.

Stojanovic, J., Milovanovic, D., Pastorino. R., Iavocoli, I., & Boccia, S. (2018). Occupational exposures amd genetic susceptiblity to urinary tract cancers: A systematic review and meta-analysis. *European Journal of Cancer Prevention*; 27(5):468-476.

Turner, S., Carder, M., van Tongeren, M., Mc Namee, R., Lines, S., Hussey, I., etal., (2007). The incidence of occupational skin disease as reported to The Health and Occupation Reporting (THOR) network between 2002 and 2005. *British Journal of Dermatology* *157*(4), 713-722.

Varella, I.S., Canti, I. C. T., Santos, B.R., Coppini, A.Z., Argondizzo, L.C., Tonin, C., & Wagner, M.B. (2009). Prevelance of acute toxoplasmosis infection among 41,112 pregnant women and the mother-to-be trasmisionratr in a public hospsital in South Brazil. *Mem. Inst. Oswaldo Crus*, 104(2): 383-8.

Winder, C. (2004). Occupational skin diseases. In Winder & Stacey, N. (Ed.). *Occupational Toxicology*. (2nd ed.) BocaRaton, FL. CRC Press.