



The Human: As a Biological System

Core Body of Knowledge for the
Generalist OHS Professional



Safety Institute
of Australia Ltd



Australian OHS Education
Accreditation Board

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The OHS Body of Knowledge for Generalist OHS Professionals has been developed under the auspices of the **Health and Safety Professionals Alliance**



The Technical Panel established by the Health and Safety Professionals Alliance (HaSPA) was responsible for developing the conceptual framework of the OHS Body of Knowledge and for selecting contributing authors and peer-reviewers. The Technical Panel comprised representatives from:



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The Safety Institute of Australia supported the development of the OHS Body of Knowledge and will be providing ongoing support for the dissemination of the OHS Body of Knowledge and for the maintenance and further development of the Body of Knowledge through the Australian OHS Education Accreditation Board which is auspiced by the Safety Institute of Australia.



Synopsis of the OHS Body of Knowledge

Background

A defined body of knowledge is required as a basis for professional certification and for accreditation of education programs giving entry to a profession. The lack of such a body of knowledge for OHS professionals was identified in reviews of OHS legislation and OHS education in Australia. After a 2009 scoping study, WorkSafe Victoria provided funding to support a national project to develop and implement a core body of knowledge for generalist OHS professionals in Australia.

Development

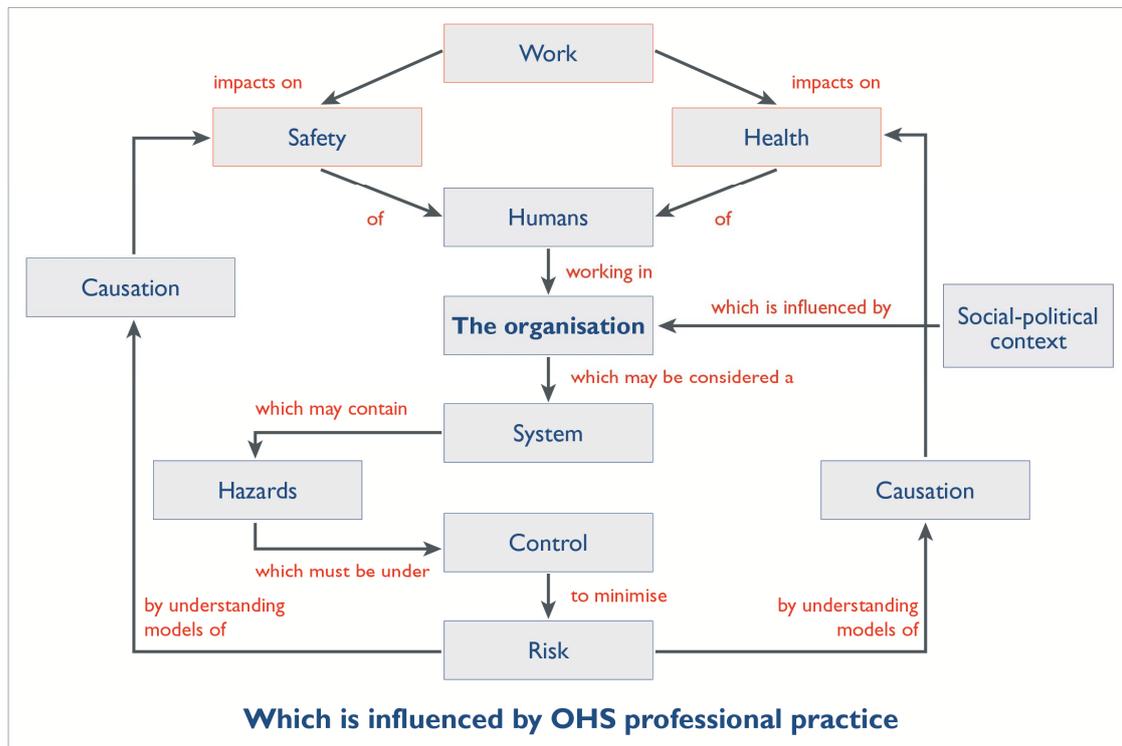
The process of developing and structuring the main content of this document was managed by a Technical Panel with representation from Victorian universities that teach OHS and from the Safety Institute of Australia, which is the main professional body for generalist OHS professionals in Australia. The Panel developed an initial conceptual framework which was then amended in accord with feedback received from OHS tertiary-level educators throughout Australia and the wider OHS profession. Specialist authors were invited to contribute chapters, which were then subjected to peer review and editing. It is anticipated that the resultant OHS Body of Knowledge will in future be regularly amended and updated as people use it and as the evidence base expands.

Conceptual structure

The OHS Body of Knowledge takes a 'conceptual' approach. As concepts are abstract, the OHS professional needs to organise the concepts into a framework in order to solve a problem. The overall framework used to structure the OHS Body of Knowledge is that:

Work impacts on the **safety** and **health** of humans who work in **organisations**. Organisations are influenced by the **socio-political context**. Organisations may be considered a **system** which may contain **hazards** which must be under control to minimise **risk**. This can be achieved by understanding **models causation** for safety and for health which will result in improvement in the safety and health of people at work. The OHS professional applies **professional practice** to influence the organisation to being about this improvement.

This can be represented as:



Audience

The OHS Body of Knowledge provides a basis for accreditation of OHS professional education programs and certification of individual OHS professionals. It provides guidance for OHS educators in course development, and for OHS professionals and professional bodies in developing continuing professional development activities. Also, OHS regulators, employers and recruiters may find it useful for benchmarking OHS professional practice.

Application

Importantly, the OHS Body of Knowledge is neither a textbook nor a curriculum; rather it describes the key concepts, core theories and related evidence that should be shared by Australian generalist OHS professionals. This knowledge will be gained through a combination of education and experience.

Accessing and using the OHS Body of Knowledge for generalist OHS professionals

The OHS Body of Knowledge is published electronically. Each chapter can be downloaded separately. However users are advised to read the Introduction, which provides background to the information in individual chapters. They should also note the copyright requirements and the disclaimer before using or acting on the information.

The Human: As a Biological System

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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. 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. Two case studies featuring the nervous system and the integumentary system provide examples of the application of physiological knowledge in the OHS context.

Keywords

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

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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. 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. It is the first of a series of three chapters that focus on humans as biological, psychological and social systems.

Firstly, this 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). Two case studies highlighting the nervous system and the integumentary system provide examples of the application of physiological knowledge to situations that a generalist OHS professional could encounter.

With musculoskeletal injuries (sprains, strains and disease) accounting for about half of all workers' compensation claims in Australia (Safe Work Australia 2011), an understanding of the musculoskeletal system is vital for generalist OHS professionals; however, the musculoskeletal system is not addressed in detail in this chapter because it features prominently in the OHS Body of Knowledge - Biomechanical Hazards. This chapter, like the 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 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.¹

2 Historical perspective

Concern for occupational health and safety developed in parallel with our understanding of the effects of work on the human body. It is recorded that miners in ancient Egypt wrapped themselves in sacks and used masks made of the bladders of animals for dust protection (Krobonja & Konton, 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:

¹ See *OHS BoK The Human: Basic Principles of Psychology* and *OHS BoK The Human: Principles of Social Interaction*

“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. 286-29)

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; Krobonja & Kontonja, 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 (Tukronja & Kontori, 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 Giovanni Scopoli described the symptoms of chronic mercury poisoning in workers in a mercury mine in Idria, Slovenia, suggested 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 the 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 Thackeray'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 before they cause ill health (Gochfeld 2005). Significantly, the 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.

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 body systems maintain *homeostasis*, which is essential for the survival of each cell, and each cell, through its specialized 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.

An understanding of the role of these 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.)

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 accessory 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, and can absorb substances. The skin consists of the epidermis (outer layer), the dermis (inner layer) and subcutaneous layer.
Cardiovascular /Circulatory	The cardiovascular system consists of the heart, blood and blood vessels, including arteries, capillaries and veins.	The heart is divided into two sides and four chambers and has walls that are made of cardiac muscle. The right side of the heart pumps blood to the pulmonary circuit, where it picks up oxygen from the lungs. The left side of the heart pumps the oxygenated blood to the systemic circuit, 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 (large 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, alveoli and diaphragm.	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. Accessory 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 transferral 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

System	Components	Function
		<p>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.</p> <p>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 by the rectum and anus.</p>
Urinary	The urinary system includes two kidneys, two ureters, the bladder, two sphincter muscles and the urethra.	<p>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.</p> <p>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.</p> <p>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.</p>
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.	<p>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.</p> <p>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 neurones:</p> <ul style="list-style-type: none"> • 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. <p>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.</p>

System	Components	Function
		<p>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 receiving external stimuli, including hearing, touch and sight.</p> <p>The autonomic 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.</p>
Endocrine	The endocrine system is composed of ductless glands and hormones. Ducts and organs involved with the endocrine system include: pituitary gland, thyroid gland, parathyroid gland, adrenal glands, pancreas and gonads (testes and ovaries).	<p>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.</p> <p>The processes that endocrine hormones are involved with include growth, repair, sexual reproduction, digestion and homeostasis (constant internal balance).</p>
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.	<p>The immune system is the body's defence mechanism, protecting it against attack by bacteria, parasites, fungi and viruses.</p> <p>The physical barriers of the skin and mucus membranes are the human body's first line of defence against attack.</p> <p>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 cells that can become phagocytic.</p> <p>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, including the two main types: humoral (antibody-mediated) and cellular (cell-mediated).</p>

System	Components	Function
Reproductive	The male reproductive system consists of the spermatozoa, testicles, epididymis, vas deferens, seminal vesicle, prostate gland, urethra, penis and scrotum. The female reproductive system consists of the ovum, ovary, fallopian tube, uterus, cervix and vagina.	The function of the human reproductive system is to produce offspring; it involves both the male and female reproductive organs.
Musculoskeletal	The musculoskeletal system includes bones, cartilage, ligaments, muscles, tendons and, in the spine, intervertebral discs.	<p>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.</p> <p>There are three different types of muscles:</p> <ul style="list-style-type: none"> • 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. <p>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.</p>

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, 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.

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 musculo-skeletal disorders resulting from hazardous manual handling tasks (Caple, Macdonald & Evans, 2005).²

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 digestive system via swallowing and the circulatory system via an intravenous route. 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. 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.

² See also *OHS BoK Causation & Health Determinants*.

6 Case studies

6.1 Scenario 1: Nervous system

Exposure to some substances in the workplace can have adverse effects on the nervous system (neurotoxicity); poisonous chemicals ó neurotoxicants ó 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 nervous system.

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 surveillance 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 surveillance 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 exposure, Sarah starts by doing some background reading. She finds that OPs are the most widely used insecticides in Australia: óAbout 5000 tonnes of active ingredients from this group, which comprises 30 identifiably distinct chemicals, have been used annuallyö (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.

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 formulating 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 surveillance 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 in the formulation process, dermal absorption is the most common route of entry when respiratory protection is used, which is the practice in Sarah's company. Also, OPs may enter 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. bronchorrhoea, bronchoconstriction), the cardiovascular system (e.g. bradycardia, tachycardia), the digestive system (e.g. abdominal cramps, nausea, vomiting, diarrhoea), 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. 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 five factors:

1. **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.
2. **Absorbed dose** – the amount and time over which the agent is taken up by the body.
3. **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].
4. **Target effect** – the response of the target to the target dose of the toxic agent.
5. **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 sequela 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). 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 levels are kept to as low as reasonable practicable (ALARP).

In terms of health surveillance for OP pesticide exposure, the physician confirms that the company is following a program that complies with the state's legislative requirements; this involves taking the person's occupational and medical history, 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. If a 20% depression of cholinesterase activity is seen, the worker is retested; if the fall is 40% or more, the worker is removed from further exposure to OPs until the level returns to baseline. 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 recently developed urinary OP metabolites test as a more immediate indicator of OP absorption (Johnstone, Capra & Newman, 2007).

OHS professional's response

Armed with this information, Sarah returns to the workplace to further investigate the company's health surveillance program. As part of this process, she secures an agreement from the company to have the occupational physician trial the use of urinary OP metabolites as well as cholinesterase activity in the surveillance of OPs.

6.2 Scenario 2: Integumentary system

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 less than 1% of all compensation claims (Safe Work Australia 2011). Based on the UK (EPIDERM) program, an occupational skin disease surveillance scheme was conducted from 2001 to 2005 in the Netherland (Pal et al.,). This scheme gathered information about occupational skin diseases, including incidence rates, casual 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 is 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, 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 ó 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. Immune system skin cells called Langerhans cells process the antigens (foreign body) and present them to cutaneous T cells (Meade, Weissman, Beezhold, 2002).

OHS professional's response

Having spoken to the occupational physician, the OHS professional takes his advice and advises Bob to visit his GP and be referred to a dermatologist. The OHS professional also obtains a copy of the Safety Data Sheet for the hand cleanser and starts to investigate alternatives.

7 Implications for OHS practice

The generalist OHS professional requires a working knowledge of the physiology of the human body³ particularly from a biological systems perspective. Provision of 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 hazards to human health.

³ See also *OHS BoK* Foundation Science.

8 Summary

Humans are complex organisms. An understanding of human physiology and, in particular, the biological systems 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 two OHS case studies.

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