01 WHAT IS EPIDEMIOLOGY?

KEY LEARNING OBJECTIVES

By the end of this chapter you will be able to:

- explain the concepts of epidemiology
- distinguish between descriptive and comparative epidemiological studies
- distinguish between experimental and observational epidemiological studies
- understand the aims of epidemiology
- understand the epidemiological process
- relate to the history of epidemiology
- describe some of the major achievements in public health.

KEY TERMS

Classification of epidemiological studies
Endemic
Epidemic
Epidemiological process
Epidemiological transition
Epidemiology
Public health
Research
Scientific method

Introduction

This book will introduce you to the basic language and principles of **epidemiology**, which is the study of factors and processes that affect **health** and disease in human populations. Epidemiological **research** delivers the basis for evidence-based medical intervention, 'best clinical practice' or **public health** policy—be it in the form of simply describing occurrences of diseases or as sophisticated modelling of interdependent factors affecting a specific health outcome.

In times when decision-making in the health sciences is required to be more and more evidence based, epidemiological research becomes increasingly important. Whether you are studying or practising as a public health professional, a doctor, or an allied health professional, the knowledge that you acquire by working through this book will enable you to read and critically assess the scientific health literature pertinent to your specific discipline. This basic skill is necessary for evidence-based decisions in all health sciences. We also hope it will guide and inspire you to carry out your own research as an Honours, Master of Public Health, or Doctoral student to add new knowledge to your particular health discipline.

This book is principally aimed at undergraduate as well as postgraduate students in all health and allied health disciplines, and draws examples from a wide range of applied health research, including, but not restricted to, public health, medicine, nursing, occupational therapy, physiotherapy, and sports and exercise sciences.

While the content of the whole manuscript is recommended for all students, undergraduate students may wish to omit some sections during their initial study. The sections essential at the undergraduate level are those listed under 'introductory level' in the table on page xxix. At the end of each chapter, further reading sections, including interesting or interactive websites, are provided for readers who require additional information.

Defining epidemiology

The word epidemiology comes from the Greek terms *epi* (meaning upon, among), *dēmos* (meaning people, district), and *logos* (meaning word, study), and literally translated means 'speaking upon people' or 'the study of people'. Thus, in epidemiology, the fundamental unit of observation is people, in contrast to animals, inanimate substances or microorganisms, which constitute the basis of investigation in other areas of health research. In epidemiological studies, information is usually collected from a group of people, several groups of people, or sometimes just one person.

Over time there have been several definitions of epidemiology. The definition from the *Oxford English Dictionary*, citing a source from 1873, is 'that branch of medical science which treats epidemics'. We will be working with a more modern definition of epidemiology, which is given in Box 1.1.

DEFINITION OF EPIDEMIOLOGY

BOX 1.1

Epidemiology is the study of the occurrence and distribution of health-related events, states and processes in specified populations, including the study of the determinants influencing such processes, and the application of this knowledge to control relevant health problems.

> 'Study' includes surveillance, observation, hypothesis testing, analytical research, and experiments.

> 'Distribution' refers to analysis by person, place, and time.

> 'Determinants' are all the physical, biological, social, cultural, and behavioural factors that influence health.

> 'Health-related events, states, and processes' include outbreaks, diseases, causes of diseases, behaviour such as use of tobacco, reactions to preventive regimens, and provision and use of health services.

> 'Specified populations' are those with common contexts and identifiable characteristics.

> 'Application … to control …' makes the aims of epidemiology explicit—to promote, protect, and restore health, and advance scientific knowledge.

Source: Based on Porta 2014

Following the definition of epidemiology given in Box 1.1, epidemiology studies the distribution of diseases and tries to answer questions such as: 'Who has the disease?'; 'How many people have the disease?'; 'When did the disease occur?'; and 'Where did the disease occur?'. For example, assume researchers want to investigate survivors of stroke in Australia with the longer term plan being to introduce a new occupational therapy intervention for stroke survivors. In order to position their project appropriately, the researchers determine that Australian men are somewhat more likely to have a stroke than Australian women, and that males are more likely to have a stroke at a younger age (60–74 years) than women. They further find that based on self-reported data from a 2003 survey, an estimated 346 700 Australians have had a stroke at some time in their lives. The researchers also find that during the last two decades mortality rates for stroke have halved for both men and women, and that there were no marked differences in mortality rates for people from rural areas or regions of lower socio-economic status (AIHW 2006; Fitzgerald 2005). All the information reported above on stroke is epidemiological information collected using epidemiological principles. The data presented address some of the typical questions used to describe the distribution of stroke: they refer to person (age, gender, etc.), place (Australia urban and rural), and time (now and 20 years ago).

Epidemiology is also interested in *determinants* of diseases, which implies, in its narrowest meaning, the identification of causes of diseases. These determinants are often called 'exposures', 'risk factors', or 'risk markers' depending on the kind of relationship under investigation and how well a potential cause–effect relationship is clarified. Determinants of disease include all the physical, biological, and behavioural factors that influence health, such as nutrition, biological agents, toxic agents, the social environment, and medical practice. Epidemiological studies that deal with the identification of determinants of disease are referred to as *analytical studies*. For example, the researchers of the above-mentioned stroke study would be well aware that smoking, physical inactivity, hypertension, and high cholesterol levels are determinants of stroke.

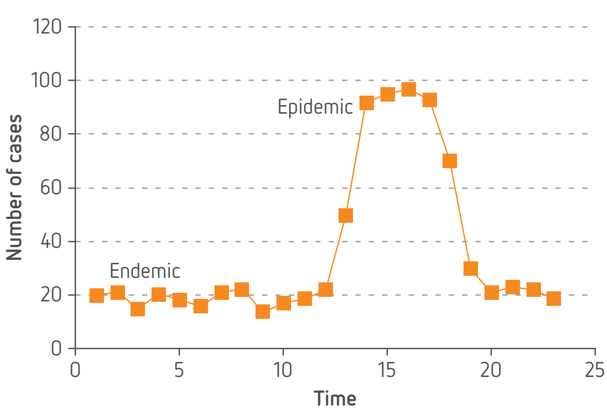
The definition in Box 1.1 refers to 'health-related states or events'. These health-related states or events incorporate more than diseases (e.g. stroke). Hence, epidemiology deals with outcomes that can be diseases, behaviours (e.g. smoking or stopping smoking, physical activity, activities of daily living), or well-being (e.g. quality of life, survival).

The definition given above is the definition of the International Epidemiological Association and is not without controversy. Eminent epidemiologist and biostatistician Olli Miettinen points out that epidemiology is 'community medicine' and an epidemiologist is 'a physician who practices community medicine…' (Miettinen 2011). However, Miettinen also describes the recent shift from community medicine to a much broader understanding of epidemiology focusing on applied epidemiologic and clinical research. Although he stresses the differences between an epidemiologist according to his definition and a person who conducts epidemiologic research ('nor is a scholar in the field of music by definition a musician'), he also concedes that, 'Epidemiological research may actually defy definition that is generally agreeable—objective in this meaning' (Miettinen 2011).

Epidemic is different from **endemic**, which is used to classify infectious diseases that are 'always in a place', but not in epidemic proportions. For example, measles can be endemic within a population, but if it is introduced to a population with no previous exposure or resistance, such as an isolated group of South American Indians, it may cause an epidemic.

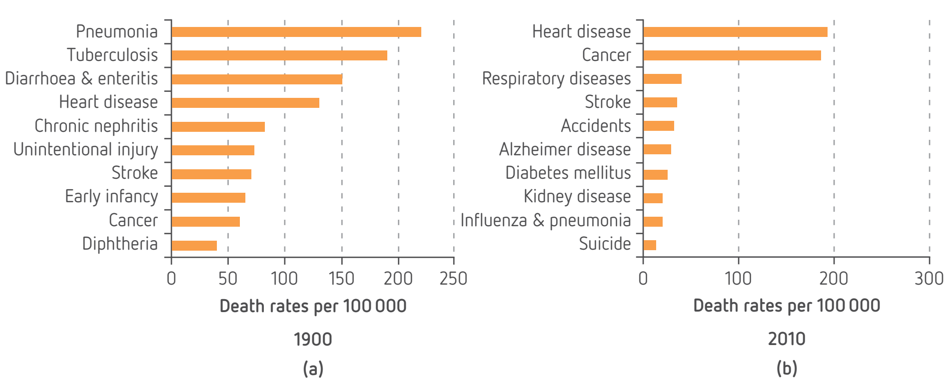
For centuries, humans worldwide suffered from outbreaks of **infectious diseases**, such as smallpox, malaria, or bubonic plague. The word **epidemic** was originally used as a name for these outbreaks of infectious diseases, and epidemiology was concerned with epidemics, that is, the occurrence of diseases in greater frequencies than would 'normally' be expected (Figure 1.1). The initial focus on infectious diseases is not surprising as infectious diseases were, and in many countries still are, the most serious diseases in humans. **Infectious disease epidemiology** raises very specific questions about agents, transmission, and immunisation (see Chapter 2). Infectious disease epidemiology provided the first models for epidemiology, with many of its general principles being adapted later to other areas of modern epidemiology.

FIGURE 1.1 A disease may be endemic within a population, with a relatively constant number of cases, but an outbreak of the disease, causing a spike in the number of cases, is an epidemic



During the eighteenth and nineteenth centuries, the Industrial Revolution changed the lifestyle of Western European and North American people forever. In Western Europe, societies that had largely been made up of subsistence farmers changed to become industrialised nations with large urban centres. By and by, Western Europeans largely abandoned farming and became industrial workers living in cities. There were similar changes in North America. Parallel to industrialisation, advances in science improved our understanding of the causes and modes of prevention of infectious diseases. For example, the germ theory changed our thinking about the causes of infectious diseases, while the development of vaccines offered protection. Basic hygiene practices became standard in hospital wards and at home, and led to a reduction in previously prominent infectious diseases, such as puerperal fever. Birth and death rates decreased, life expectancies increased, and **chronic diseases** eventually took over as the major causes of death (Figure 1.2). These complex changes are known as the **epidemiological transition**. The influence of this transition changed the focus of epidemiology from infectious to chronic diseases in the second half of the last century. Chronic diseases are generally diseases of longer duration; they rarely resolve spontaneously. Chronic diseases often lead to a loss of function, impairment, and long-term disabilities, which is why they are also frequently called degenerative diseases. Typical chronic diseases include cardiovascular diseases, cancer, diabetes mellitus, asthma, and musculoskeletal diseases. Please note that the differentiation between chronic and infectious disease is by no means straightforward and might be misleading (Weisz 2014). Not all infectious diseases occur only in acute outbreaks. On the other hand, many chronic diseases are caused by an infectious agent; for example, cervical cancer is caused by human papillomavirus, and liver cancer can be caused by hepatitis B and C viruses. Many patients with an infectious disease require long-term care just like patients with a 'chronic' disease. For example, human immunodeficiency virus (HIV) has become a chronic disease in many countries (Choi et al. 2007).

FIGURE 1.2 The 10 leading causes of death in the United States, (a) 1900 and (b) 2010



Source: Grove & Hetzel 1968; Murphy et al. 2013

Approximately 2500 years ago, Pericles (495–429 BCE), a prominent Athenian statesman and general, defined *health* as 'a state of moral, mental and physical well-being', and our current understanding of health is not very different from this ancient concept. In 1948, the World

Definitions of health usually relate to individuals or cultural groups. That is, the perception of being healthy might differ from person to person or from group to group.

Health Organization (WHO) defined health in the preamble to its constitution in a very similar manner as 'a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity'. These definitions give an idealised concept of health and should not be interpreted too literally. However, they clearly took health beyond the absence of disease and set the scene for current thinking about public health issues.

In more recent times, epidemiology has become a decision-making tool in public health and social policy. A classic example of the rise of epidemiology as an important instrument in health policy is the epidemiological research relating to the impact of cigarette smoking on health. The combined evidence of the studies conducted by Sir Richard Doll and Sir Austin Bradford Hill (Doll & Hill 1950) and many others has finally resulted in the enactment of various pieces of legislation in Australia, including increased sales tax on tobacco, control of sale of tobacco to minors, the control of smoking in public places, and plain cigarette packaging. In general, health service providers and administrators often base their decisions on the results of epidemiological studies and general epidemiological surveillance to answer questions such as 'What services are needed?' and 'What effects have the services had on the health of the community?'

Actions that aim to improve the health of the general population fall into the broad domain of public health. These actions may be based on data from epidemiological studies. *Public health* is a multidisciplinary set of activities concerned with the protection and promotion of the health of communities, and the delivery of services to the community. There are many definitions of public health. According to *A Dictionary of Epidemiology*, public health has four dimensions including 'The health of a whole society'; all policies, programs and efforts organised and conducted by society to collectively protect, promote, and restore the people's health; all institutions and organisations which plan, fund and implement these efforts; and the scientific disciplines and professions which influence health determinants positively and promote health (based on Porta 2014). As you can see from these characterisations, public health is broad and hugely important, as it potentially affects all our lives. Public health encompasses everything from breast cancer screening to immunisation programs, from monitoring water quality to running hospitals, from routine collection of health data to the development of health policies. The results of epidemiological studies provide the scientific reasoning behind public health actions.

Epidemiology is the scientific method of public health.

Modern epidemiology is an interdisciplinary science that draws from medicine and medically related disciplines (e.g. pathology, virology, and genetics), from biostatistics, and from social and behavioural sciences. Thus, epidemiology is an extraordinarily rich and complex science that uses techniques and methodologies from many disciplines.

The following is a partial list of important aims of epidemiology. The aims of epidemiology mirror its definition:

» description of natural history of disease
» description of the health status of a population (disease burden in community)
» identification of causes of disease (disease aetiology)

- explanation of local disease occurrence (e.g. outbreak of infectious disease)
- identification of prognostic factors (factors influencing survival)
- identification of 'best' treatment (therapeutic trials)
- prevention of disease and the evaluation of preventive measures
- evaluation of health-related programs and health services
- guidance of administrators of health services and legislators in their decision-making process.

We will refer back to these aims throughout the book.

CRITICAL THINKING EXERCISES

Exercise 1.1

Define:

(a) Epidemic (b) Endemic (c) Epidemiology

Exercise 1.2

Give examples of infectious diseases for which only a few cases would represent an epidemic in Australia or New Zealand.

Exercise 1.3

Choose some of the aims of epidemiology listed above and give examples of studies or work which fall under these aims.

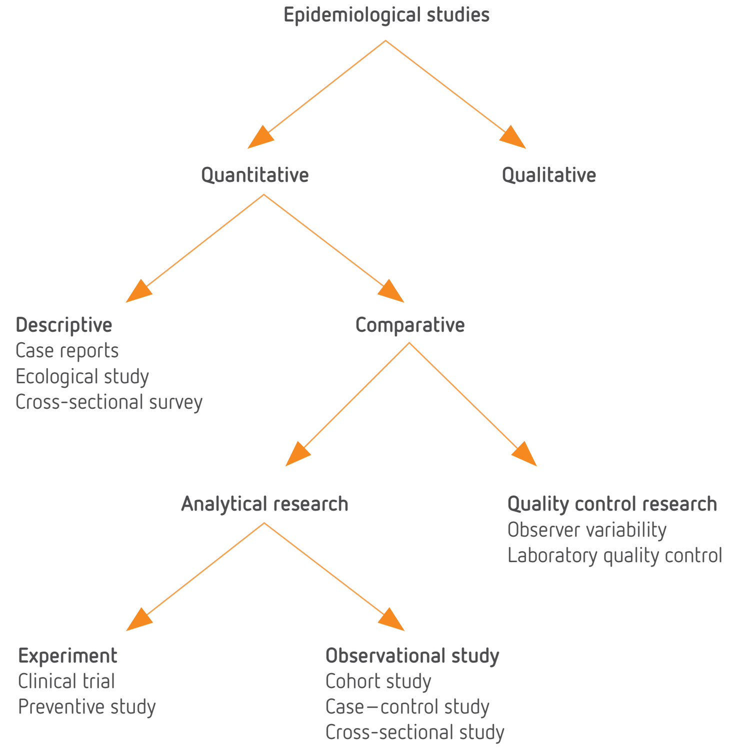
Classification of epidemiology

Epidemiological studies and research in general can be classified in several different ways. The hierarchical classification shown in Figure 1.3 is a modified version of Alvan Feinstein's (1985) suggestion. Figure 1.3 provides one possible classification of epidemiological studies; other books might suggest slightly altered categorisations, while some authors suggest radically different approaches (Pearce 2012). Here, the first principal differentiation is between quantitative and qualitative epidemiological research. **Qualitative epidemiology** is exclusively descriptive and usually studies a small, deliberately selected group of people in detail. Often the study group is formed by key 'information-rich' people who are researched using interviews or discussions guided by the investigator. It is not unusual for the questions or discussion points to be modified during the research process. After the completion of the interviews, the investigator identifies the main topics and themes raised during the data collection, thus providing a detailed description of the people researched.

Qualitative research is concerned with the individual experience or process. Quantitative research is aimed at the wider, general population; the result of quantitative research is information about the 'average' person or outcome.

Quantitative epidemiology, in contrast, aims to collect information on many people who are representative of the general population rather than a selected group of key people. The intention is to draw inferences from the study sample and relate them to the wider population. The information gathered is strictly predefined and measured as consistently and accurately as possible. Results are assessed using statistical analysis.

FIGURE 1.3 Classification of epidemiological studies



Source: Based on Feinstein 1985

From an historical perspective, qualitative research was undoubtedly used before people started to quantify health issues. However, nowadays, quantitative epidemiology can be regarded as the main branch of epidemiology, while qualitative epidemiology is seen as a research discipline in its own right. The two methodologies complement each other and many researchers conduct studies using both types of methodologies; such studies are called 'mixed methods' research.

CASE STUDY 1.1

Identifying and understanding the factors affecting infection control and Hendra virus management in private veterinary practices in Queensland, Australia

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I hold a Bachelor of Veterinary Science equivalent (Ecole Nationale Vétérinaire de Nantes, France), a Master of Public Health (James Cook University), and am currently undertaking doctoral studies in veterinary infection control. The first outbreak of Hendra virus (HeV), a zoonosis transmitted from bats to horses (mortality rate 75%) and, in some cases, from horses to humans (mortality rate 57%), occurred in Australia in 1994. Since then, seven people have been infected with HeV and only three have survived. All infected people were involved with either

CASE STUDY CONT ...

the horse or veterinary industries (a horse trainer, a stablehand, a lay person assisting a veterinarian during a necropsy, three veterinarians and a veterinary nurse). The emergence of HeV has highlighted deficiencies in infection control standards among the Australian private veterinary workforce, even though these people are at higher occupational risk of exposure to zoonoses (infectious diseases that are transmissible from vertebrate animals to humans). Previous studies have shown that veterinary infection control is less than optimal in Australia but did not explain infection control behaviours among veterinarians. Quantifying behaviours gives little insight into the motivations behind these behaviours, and one can only speculate on what these may be. Social and health behaviours have long been studied qualitatively—a methodology that is well established and accepted in these fields but seldom used in veterinary sciences. Between 2009 and 2010, my colleagues and I took the novel approach of conducting an exploratory qualitative study to identify and understand the factors influencing infection control behaviours and HeV management in private veterinary practices in Queensland, Australia.

This study consisted of a series of face-to-face, in-depth interviews with 18 private equine veterinarians and 3 allied staff (2 veterinary nurses and 1 practice manager). Participants were recruited from 14 different private practices located in urban, rural and remote areas in the known distribution range of HeV between Far North and south-east Queensland in 2009–10. The majority of participants had dealt with at least one potential HeV outbreak. Participants were asked a number of open-ended questions on the topics of HeV and its management, infection control, and workplace health and safety. Thematic analysis of the data revealed that participants agreed with the need for improvements in veterinary infection control and HeV management. However, they also agreed that bringing about these changes had been and remained challenging for a range of reasons, including low HeV-related risk perception when the disease first emerged, which prompted little action from the profession and government authorities; insufficient and uneven government support to private veterinarians across the affected region; recurrent underestimation of the occupational importance of zoonoses within the veterinary work culture; time and financial cost of implementing new infection control measures as well as fulfilling biosecurity and public health roles while running a private business; and risk and safety communication challenges between government authorities, veterinary staff and clients. Behaviour changes were more likely to occur when HeV risk was adequately perceived, participants had a personal interest in infection control and zoonoses, or participants had previously dealt with confirmed cases of HeV or other zoonoses (such as equine influenza).

Qualitative research proved to be a valuable approach to understanding veterinary infection control and HeV management behaviours by putting these behaviours into the context of private equine veterinary practice. The outcomes of this qualitative exploratory study concurred with other reports on the management of HeV and equine influenza by government authorities and the veterinary profession, and the results from three quantitative follow-up studies. Triangulation between previous, concurrent and subsequent reports strengthened the overall conclusion that slow-emerging zoonoses may need a different management approach to rapidly emerging ones, and the private veterinary workforce needs to be better prepared, supported and consulted with if they are expected to fulfil a public health and biosecurity role when new zoonoses emerge.

Interestingly, publishing these qualitative results proved to be a challenge because: 1) most target veterinary journals were unfamiliar with the methodology used, and reviewers criticised manuscripts on quantitative bases only; and 2) public health journals that publish qualitative research more readily saw the issues presented

CASE STUDY CONT …

as only relevant to the veterinary field, despite the public health role of private veterinarians dealing with a HeV outbreak. Nevertheless, patience, persistence, and the provision of informative responses to reviewers eventually yielded three publications in traditionally quantitatively oriented journals and a poster presentation at an Australian conference on zoonoses. Christley and Perkins have since highlighted that qualitative research could be a valuable tool in hard-to-understand areas of veterinary sciences. It is a tool regularly used in public health research and should also gain its place in veterinary public health research.

Sources: Christley & Perkins (2010); Mendez et al. (2012a, 2012b, 2013, 2014).

This book addresses the quantitative approach to epidemiology and does not cover qualitative or mixed method approaches. There are numerous books introducing qualitative (e.g. Liamputtong & Ezzy 2006) and mixed methods research (e.g. Creswell & Plano-Clark 2007). The discussion of study design in our book follows the classification detailed in Figure 1.3—quantitative epidemiology is first categorised into descriptive and comparative studies.

The most important feature of comparative research is the definition of a control group against which comparisons are carried out.

Descriptive studies do exactly as their name suggests; they describe patterns of disease occurrence in relation to variables such as person, place, and time. Descriptive research provides data that are used only for descriptive purposes. Descriptive studies are often used in health service research to provide information about cost and apparent need for medical care. Another example is a case report or a case series of interesting or maybe previously unreported symptoms, behaviours, or events. Classic examples are the case reports of Kaposi's sarcoma and *Pneumocystis carinii* (now known as *P. jiroveci*) pneumonia noted in the early 1980s by the United States Centers for Disease Control and Prevention, which raised the first alarms about the disease we now know as HIV/AIDS (Kanabus & Fredriksson 2010). Quantitative descriptive studies are further described in Chapter 6.

Comparison is one of the hallmarks of scientific activity, and studies involving a comparison to a control group constitute the *analytical* epidemiological study approach—the mainstream of *comparative* epidemiological study. Analytical studies assess the effect(s) of potential aetiological agents (causes of disease), pathogenic mechanisms, risk factors, prognostic factors, or remedial therapy.

Any measurement, including measurements obtained using an instrument or data collected by questionnaire or recorded by a person, should be valid and reproducible.

Quality control research, the second branch of comparative epidemiology, deals with methods to assess and maintain measurement quality—mainly with respect to instruments in the medical laboratory but also with respect to intra- and inter-observer agreement in general. Thus, quality control research forms the basis for any quantitative research. However, the specific methodologies of quality control research are not generally introduced in this book. Only one example of quality control research—studies that assess sensitivity and specificity of a screening or diagnostic tool—will be discussed in some detail in Chapter 3.

Mainstream analytical epidemiology is further divided into the major branches of *experimental studies* and *observational studies*. In experiments, the exposure (often an intervention) under study is actively and deliberately managed by the investigator; for example, one group is given the new drug, while the control group receives an inert placebo. In contrast, in observational studies, the investigator only observes exposure without actively managing it; for example, a group of smokers is compared to a group of non-smokers. Experimental studies will be discussed in some detail in Chapter 7, while Chapter 8 deals with the main observational study designs. Box 1.2 provides some examples of experimental and observational studies.

EXAMPLES OF EXPERIMENTAL AND OBSERVATIONAL STUDIES — BOX 1.2

Example 1

An Australian study is investigating whether a very early mobilisation (VEM) program administered to an intervention group by a combined nurse and physiotherapy team is effective in reducing the number and severity of complications after stroke when compared to a control group without VEM.

Comment:

This comparative research is clearly an experimental study (a therapeutical trial) since the intervention—VEM—is actively managed by the researchers: VEM is administered to some stroke patients (intervention group) but not to others (control group).

Source: Sorbello et al. 2009

Example 2

A study by an occupational therapy team from Queensland investigated the functional consequences of a traumatic hand injury on people living in rural or remote Australian locations. The study described the experiences of a case series of hand-injured adults using a survey. It found that almost 90% of survey respondents had residual difficulties as a result of their hand injury and that the overall impact on day-to-day life was moderate to extreme for more than half the respondents.

Comment:

This is a descriptive study. The entire group of hand-injured respondents was described and no comparisons were made to a control group.

Source: Kingston et al. 2010

Example 3

Investigating the growing issue of obesity, researchers in Dunedin looked at the association between childhood sleep time and the long-term risk of obesity. The cohort used was the general-population birth cohort of 1037 participants born between April 1972 and March 1973 in Dunedin. Within the study group, parental reports of sleeping times at different ages were associated with adult body mass index.

Comments:

1 This comparative study is an observational study, a so-called cohort study. The 'exposure' (study factor) was sleep time during childhood and the outcome was 'adult obesity'. The researchers did not manage the study factor—the childhood sleeping time of their

participants (this would have been very impractical and probably also unethical). The childhood sleeping time was just 'observed', so this defines the study as observational.

2 It is important to note from a design point of view that experimental studies are preferable to observational studies as they allow a certain control during the study which is not possible with observational designs. However, it is very often impractical or unethical to vary the exposure level and to conduct an experimental study. Imagine you would like to conduct a study on the effects of smoking in people. An experimental design would imply that you allocate the number of cigarettes smoked by your participants; so, according to your allocation, some people would have to smoke 20 cigarettes per day, others 50 and again others none at all for several years of follow-up. Naturally, such a design is completely unacceptable and the only way left to study the effect of smoking is observation! This restriction applies to numerous other human behaviours, such as alcohol consumption, sun exposure, safe sex and childhood sleeping time.

Source: Landhuis et al. 2008

Example 4

A study conducted by Macquarie University, NSW, compared children with specific language impairment (SLI) and children with specific reading disability (SRD) with a control group of children with no language or reading disabilities for their processing of passive auditory event-related potentials to tones, rapid tones, vowels, and consonant-vowels. The study concluded that impaired auditory processing is a potential risk factor for both SLI and SRD.

Comment:

This study is a comparative, observational study, a so-called case–control study. The 'exposure' (study factor) was impaired auditory processing and the outcome was 'SLI' and 'SRD'. Obviously, the researchers did not vary impaired auditory processing of their participants. Rather, the impaired auditory processing was just 'observed' (measured). This defines the study as observational.

Source: McArthur et al. 2009

Example 5

Researchers at the Queensland University of Technology developed a valid and reliable instrument to measure substance-related expectations in relation to cannabis, the Cannabis Expectancy Questionnaire, specifically for men who have sex with men (MSM).

Comment:

This study is an example of quality control research. The researchers developed a questionnaire that reliably (comparisons of repeated applications to the same people give identical results) and validly (the questionnaire measures what it is supposed to measure) assesses substance-related expectations. This questionnaire can now be used in studies of MSM in Australia.

Source: Mullens et al. 2010

Further classifications of epidemiology

Classifying epidemiological research according to the disease under study led to the development of **disease-centred epidemiology**. Cancer epidemiology, injury epidemiology, psychiatric epidemiology, and reproductive epidemiology are examples of disease-centred epidemiology. The focus on only one disease (e.g. breast cancer or mental disorders) allows specialisation and usually results in substantial gains in understanding of the causes of this disease or a disease cluster. However, disease-centred epidemiology may not provide the whole picture when identifying protective measures as there may be conflicting requirements for the prevention of different diseases. For instance, overwhelming evidence suggests that sun exposure is *the* environmental cause of skin cancer. However, complete avoidance of the sun cannot be recommended as vitamin D is produced in the skin by exposure to sunlight.

Determinant-centred epidemiology focuses on exposures rather than outcomes. For example, while a disease-centred approach may study cancer and identify fat intake as a potential risk factor, a determinant-centred approach would focus on the impact of nutrition on health in general. Nutritional epidemiology is an excellent example of determinant-centred epidemiology and could investigate, for example, the impact of a high-fat diet on health outcomes. Other examples of determinant-centred epidemiology are social epidemiology, genetic epidemiology, and the epidemiology of physical activity.

Another possible classification of epidemiology differentiates between **classical public health epidemiology** and **clinical epidemiology**. *Clinical epidemiology* (clinical, from the Greek *klinikos*, meaning 'bed') refers to sick people and the activities conducted in the care of patients. Clinical epidemiology studies the diagnosis, prognosis, and therapy of patients. According to *A Dictionary of Epidemiology*, clinical epidemiology is the application of epidemiological knowledge, reasoning, and methods to study clinical issues and improve clinical care (Porta 2014). Classical public health epidemiology seeks to identify causes and measures the risk of disease, whereas clinical epidemiology uses the information from classical epidemiology to aid decision-making about identified cases of disease.

In his book *Clinical Epidemiology*, Alvan Feinstein (1985) drew the distinction between classical and clinical epidemiology in a different way. He suggested that 'the denominators' of the research can be taken as a guide for differentiation. For the various outcomes calculated from a study based in classical public health epidemiology, the denominator usually consists of the general population. For example, a study that aims to determine the incidence of lung cancer in Australia would count new cases of lung cancer over a specific period of time and divide the result by the total number of the Australian population (obtained from the Australian Bureau of Statistics) for this period of time. According to Feinstein, this study belongs to classical public health epidemiology. In contrast, in clinical epidemiology, the denominator is usually a clinically defined group. For example, a study that aims to identify risk factors for lung cancer may compare a group of lung cancer patients with a group of healthy individuals with respect to their smoking history, exposure to asbestos, age, gender, and so on. Calculation of, for example, the proportion of active smokers in each of the two groups would define denominators based on the lung cancer patients and the control group. Thus, according to Feinstein, this study belongs to clinical epidemiology.

Unfortunately, differences in the use of epidemiological terminology occur frequently and the above example is just one of many. There is no right or wrong terminology, as definitions are just descriptions of the way words are understood. However, we encourage all readers of this book to use epidemiological terms as defined by *A Dictionary of Epidemiology* (Porta 2014).

This dictionary is supported by the International Epidemiological Association and, thus, agreed on by many epidemiologists. It is the most comprehensive collection of epidemiological terminology available.

CRITICAL THINKING EXERCISES

Please classify the following studies as: descriptive or comparative, analytical or quality control, and experimental or observational, as appropriate.

Exercise 1.4

(a) A study investigated the occurrence of trachoma in an Indigenous community in Australia. The frequency of trachoma was presented for the community.

(b) A study investigated the agreement between assessors of photographs of the tarsus used for trachoma grading.

(c) A study investigated risk factors for trachoma in Indigenous Australian children. A group of children with trachoma was compared to a group of children without trachoma with respect to living conditions and hygienic behaviours of the families.

(d) A study investigated whether an educational program on facial cleanliness and hygienic procedures for Indigenous Australian parents can reduce the occurrence of trachoma in children.

Source: Adapted from Taylor et al. 2010

Exercise 1.5

A study conducted in Queensland investigated the impact of a train-the-trainer program on the nutritional status of older people living in nursing homes. Residents from four nursing homes were selected for a nutrition education program, while residents from four other nursing homes received standard care (= control group).

Source: Gaskill et al. 2009

Exercise 1.6

Currently, a large New Zealand study is investigating the effect of an active video game intervention on body mass index, percentage body fat, waist circumference, cardiorespiratory fitness, and physical activity levels in overweight children. Overweight children are separated into two groups: one group will receive the active video game upgrade package, while the other group will not (= control group).

Source: Maddison et al. 2009

The epidemiological process

So far we have presented a definition of epidemiology and briefly discussed the aims of epidemiology. Now the question remaining is, how does epidemiology work? We will discuss the mechanism of epidemiology in detail in the coming chapters; however, there is a theoretical framework guiding all epidemiological studies, which we will introduce here. This **epidemiological process** is imbedded in the principles of acquiring new knowledge in general.

It addresses the question of how research in the health sciences (and in other disciplines) should be conducted. Box 1.3 provides a definition of research.

DEFINITION OF RESEARCH

BOX 1.3

Research is understood as 'a class of activities designed to develop or contribute to knowledge'. 'The goal is generalizable knowledge which consists of theories, principles, relationships, products, or the accumulation of information on which these are based, that can be corroborated by acceptable scientific methods of observation, inference, or experiment'.

Or, more succinctly: research is an organised quest for new knowledge based on curiosity or perceived needs.

Hence, research is about finding new knowledge—knowledge that can be generalised. Research tries to answer questions, such as: How knowledgeable are children in the areas of physical fitness, diet, and exercise?; Is obesity in children on the rise in New Zealand?; Does the consumption of soft drinks add to rising obesity in Australia?; Will a musical intervention reduce aggressive behaviour in elderly people with dementia?; Do people who are afraid of going to the dentist have poorer dental health?; Can the health outcomes for newborns in Cambodia be improved by a dietary supplementation intervention for pregnant women?; and so on.

New knowledge is acquired by 'acceptable' methods. Epidemiology provides these acceptable methods for us. As stated previously, epidemiology is the scientific method of public health. The methods used in epidemiology have to adhere to ethical standards and need to be reproducible by other researchers.

Source: Based on Porta 2014

Thus, research is conducted to contribute to knowledge by using 'acceptable' scientific methods. This means we cannot go about research just as we please but, rather, we have to adhere to certain standards. The **scientific method** specifies these standards. It tells us:

- how knowledge should be acquired
- the form in which knowledge should be stated
- how to evaluate whether the information is true or false.

Today's scientific method developed over a period of several centuries, concomitantly with the growth of modern scientific research. Before the era of enlightenment (seventeenth to eighteenth centuries), philosophy, mathematics, and meta-physics were seen as the main scientific disciplines, developed by means of deductive reasoning, while only astronomy was based on observations. In the seventeenth century, René Descartes and others established a framework for scientific enquiry founded on observations and measurements. As a consequence, scientific disciplines, such as physics, chemistry, biology, and later medicine, which are all based on observations and which use inductive logic, gained importance.

It is beyond the scope of this introductory text to outline the scientific and philosophical history of the scientific method. If you are interested, good starting points are Bertrand Russell's *History of Western Philosophy* (1946), Thomas Kuhn's *The Structure of Scientific Revolutions*

(3rd edition, 1996) and Karl Popper's *The Logic of Scientific Discovery* (1959). Here, we will only introduce three basic elements of the scientific method:

» Scepticism

  This refers to the notion that any proposition or statement, even when made by great authorities, is open to doubt and analysis. Scepticism implies that every authority can be questioned. This was not always the case. In former times, people would rely heavily on authority and some 'scientific' dogma would remain standard thinking or practice just because the dogma originated from a famous authority.

» Determinism

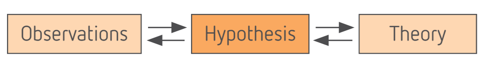
  This refers to the notion that events in the world occur according to regular laws and causes. The scientific community believes that there are laws that govern our universe and science is trying to unravel those laws. For example, the law of gravity attracts two objects with mass. We observe and experience gravity as a force that keeps us earth-bound. Laws of biology and chemistry guide medical processes.

» Empiricism

  This refers to the notion that enquiry ought to be conducted through observation and verified through experience. Observations are fundamental to all empirical sciences, such as physics, chemistry, biology, and medicine. We observe and measure objects or people and, based on these observations, we develop our understanding of the world.

The scientific method in its most simplified version is depicted in Figure 1.4.

FIGURE 1.4 The scientific method



The hypothesis is of essential importance in science and forms the core of each scientific enquiry. The accepted principle of the scientific method is falsification. Hence, a scientifically acceptable hypothesis has to be stated in such a way that it will be falsifiable. This principle goes back to the Austrian philosopher *Karl Popper* (1902–94), who stated: 'A theory is scientific if it is falsifiable' (Popper 1959). In a critical sense, Popper's understanding of science, formulated in his 'Theory of Demarcation', was based upon his understanding of a logical asymmetry, which holds between verification and falsification. It is logically impossible to conclusively verify a universal proposition by reference to experience (i.e. by induction), but a single counter-instance conclusively falsifies the corresponding universal law. The example usually given is the hypothesis that 'all swans are white'. In order to verify this hypothesis, one would need to look at all swans—a rather tedious, impractical, even impossible proposition. However, if we know about one black swan, we have conclusively falsified the hypothesis.

Popper's famous statement was that 'The failure to falsify a falsifiable hypothesis is the best support for its verity'. Therefore, a hypothesis that we failed to falsify will be accepted as true for the time being until a future study or observation proves the hypothesis wrong. This understanding of the scientific approach stresses the fact that science is in continuous flux.

Having proposed a hypothesis, one needs to ask whether there is sufficient evidence to justify its plausibility and whether it is testable (i.e. falsifiable).

Not all statements are falsifiable and, thus, not all statements can be scientifically assessed.

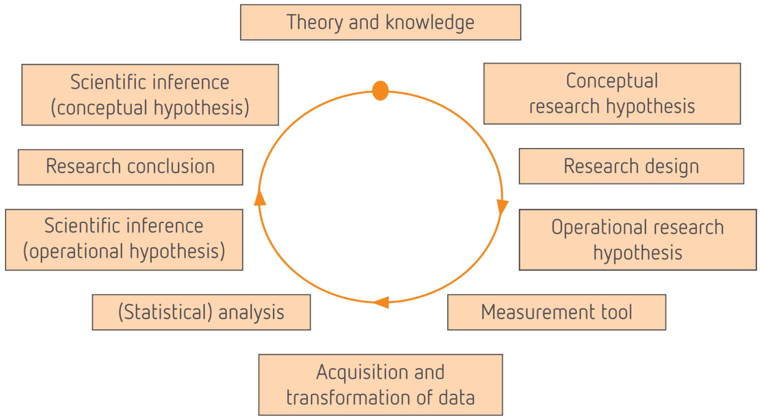
For example, your perception of the colour blue might be completely different from someone else's. But you both call it blue (by convention) although what you see might actually be someone else's red. The hypothesis that we perceive colour identically cannot be falsified. The development of meaningful and, at the same time, falsifiable hypotheses is one of the main tasks of science. We will focus further on the scientific hypothesis in Chapter 5.

Figure 1.4 shows that the scientific method works in cycles: some observations might form the basis for a new hypothesis that requires testing; the results may or may not alter theories, leading to new hypotheses, for which observational evidence may or may not be established. Or, in reverse, a theory leads to certain hypotheses, which lead to experimental observations, which might or might not support the hypotheses and, therefore, the theory. A *theory* is a set of statements that attempts to explain a set of facts, giving them a structure. A theory is used to describe, explain, or predict events or behaviours. Examples of well-known theories are the Big Bang theory to explain the beginning of our universe or the Theory of Relativity formulated by Albert Einstein (1879–1955). Lately, there has been a vibrant discussion in neuroscientific circles about how the brain functions. A new theory of brain plasticity has been proposed (Doidge 2007) in place of the established view that the nervous system is fixed in adults ('hard wiring'). This new theory was based on experimental observations.

The scientific method is by no means unanimously accepted but undergoes constant critical evaluation and should not be seen as fixed. Major controversies relating to the scientific method are: (1) whether observations are truly *independent* of the observer or whether the theory specifies what is to be observed and how; (2) the validity of *induction*, that is, whether the observation of a limited number of persons can be sufficient to induce general statements that are always true or always false; (3) the problem of *falsification*, that is, new empirical evidence that contradicts current theory does not necessarily falsify the theory but may lead to it being modified.

The core structure of the scientific method, which is shown in Figure 1.4, has been expanded in Figure 1.5 to suit epidemiology.

FIGURE 1.5 An idealised concept of the epidemiological process



Source: Adapted from Kleinbaum et al. 1982

Figure 1.5 provides the main structure of epidemiological research and the later chapters of this book follow the logical order of this research cycle.

Our knowledge about 'health-related states or events' is gradually modified and expanded by means of epidemiological studies. Quantitative studies should ideally be conducted following the research cycle shown in Figure 1.5. In reality, Figure 1.5 represents a spiral as we hopefully have improved theory and knowledge after each research cycle. Figure 1.5 depicts one ideal research cycle—the epidemiological process.

Theory and knowledge, as well as previous experience, lead to the formulation of a new research hypothesis. We can differentiate between a conceptual and an operational research hypothesis. The conceptual research hypothesis is the initial idea for the research. Issues related to the study design, experience, and feasibility, including finances and time frame, will shape this idea into an operational research hypothesis. This operational research hypothesis is falsifiable and will be investigated using empirical observations in the form of a planned study. Research design and operational hypothesis are closely intertwined. The necessary data will be collected according to a set protocol with standardised measurement tools. The raw data will be collected in a suitable format, summarised appropriately, and analysed by testing the operational hypothesis statistically. The results of the study will lead to research conclusions that allow us to add to or modify existing theory and knowledge.

According to Figure 1.5, the first step of every epidemiological research study should be a comprehensive understanding of the current knowledge and theory about the topic of interest. A *literature review* and critical input from fellow researchers are essential—research does not happen in isolation and should be regarded as a combined and concentrated effort to increase knowledge for the benefit of humankind. Chapter 5 deals with the literature review in some detail. The second step is to formulate the operational research hypothesis, that is, the question the research will aim to confirm or reject. In quantitative epidemiology, this hypothesis should be a complete and quantitative precise statement about what the study is set up to achieve (see Chapter 5 for further details). The *study design* and the development of the research hypothesis are closely interlinked. Different types of studies, their applications, advantages, and disadvantages will be discussed in detail in Chapters 6, 7, and 8. The remainder of the research cycle is related to developing measurement tools, such as questionnaires, conducting the research, entering the collected information into a database, and analysing the data statistically. Ultimately, the vast majority of quantitative studies will use statistical techniques to test (and attempt to falsify) the stated research hypothesis. Finally, research results should be published in order to be accessible for other scientists and to become part of the available knowledge.

Epidemiological studies can be large and expensive, often involving hundreds of participants. It is, therefore, crucial to the success of any epidemiological study to develop a written *study protocol* in which all steps described in Figure 1.5 are outlined in detail.

CRITICAL THINKING EXERCISES

Exercise 1.7

Using 'obesity in Australian children' as an example, explain the step-by-step process of epidemiological research.

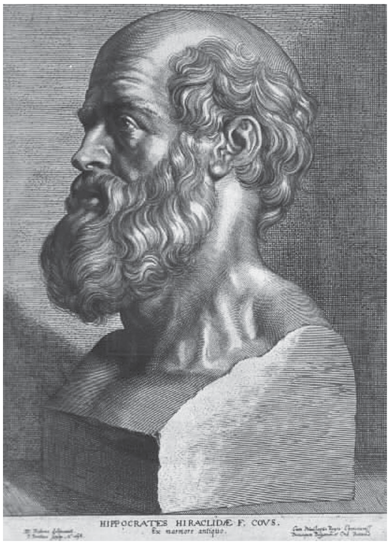
A brief history of epidemiology

From a Western perspective, public health and epidemiology have their known origins in antiquity, when Greek physicians philosophised about health and disease. The current fundamental objective of epidemiology—to understand the relationship of the disease experience of a population to its environment—has still surprisingly many similarities with *Hippocrates' dictum* formulated some 2400 years ago:

> Whoever wishes to investigate medicine properly should proceed thus: in the first place to consider the seasons of the year, and what effects each of them produces. Then the winds, the hot and the cold, especially such as are common to all countries, and then such as are peculiar to each locality. In the same manner, when one comes into a city to which he is a stranger, he should consider its situation, how it lies as to the winds and the rising of the sun; for its influence is not the same whether it lies to the north or to the south, to the rising or to the setting sun. One should consider most attentively the waters which the inhabitants use, whether they be marshy and soft, or hard and running from elevated and rocky situations, and then if saltish and unfit for cooking; and the ground, whether it be naked and deficient in water, or wooded and well watered, and whether it lies in a hollow, confined situation, or is elevated and cold; and the mode in which the inhabitants live, and what are their pursuits, whether they are fond of drinking and eating to excess, and given to indolence, or are fond of exercise and labor.
>
> *Source: Hippocrates of Cos (about 460–370 BCE) On Airs, Waters, and Places (1938)*

Greek philosophers described the four humours—phlegm, blood, melancholy, and choler—which were believed to be responsible for health, and they also described *miasma*—foul emanations—which were thought to be responsible for the transmission of disease. Despite the emphasis Hippocrates put on the role of environmental and social factors in causing human disease, he suggested that, for example, cancer was a disease caused by an excess in 'black bile', which was produced by the spleen and the stomach but not the liver. These ideas dominated medical practice through to the Middle Ages (500–1500 AD) and it was only with the advent of the Renaissance (fourteenth to seventeenth centuries) that they were questioned.

FIGURE 1.6 Hippocrates—engraving by Peter Paul Rubens, 1638



Source: United States National Library of Medicine

Some hundred years after the Greeks, Roman engineers developed a sense of environmental sanitation by supplying clean water for their citizens through the aqueduct system. Today, impressive ruins of several public thermal baths in Rome provide evidence of the fondness of the Romans for hygienic behaviour some 2000 years ago (Lawson & Bauman 2001). Other public health initiatives may have been reflected in religious beliefs, with the possibility that the origin of many ancient religious practices were based on learnt or observed behaviours to avoid diseases (e.g. the avoidance of pig meat because it was likely to be infested with parasites). In the Middle Ages, several relentless epidemics of infectious diseases occurred throughout Europe. In particular, epidemics of the bubonic plague, smallpox, and leprosy swept through Europe, with a huge impact on population size. In the fourteenth century, the bubonic plague alone is believed to have killed 25 million people, about one-third of the European population (Porter 1996). As a consequence, measures such as quarantine regulations and isolation of infected patients were undertaken to limit outbreaks of these diseases. It is interesting that these public health measures were not based on a scientific understanding of infectious disease causation.

In contrast to the lifestyle in the cities of the Roman Empire, hygienic conditions during medieval times were appalling. It was commonplace for rows of latrines to overhang rivers in England and other countries, resulting in faecal contamination of water. Slaughter houses were primitive and unhygienic. Public baths were the order of the day and personal cleanliness was uncommon.

By the end of the eighteenth century, serious investigations were undertaken by *Edward Jenner* (1749–1823), an English scientist (Bazin 2000). Jenner's work led to a smallpox vaccine through vaccination with the cowpox virus, vaccinia (the Latin word *vacca* means cow). Edward Jenner became very interested in smallpox, which was a worldwide scourge in his time. In the late eighteenth century, 400 000 people died from smallpox each year and a third of the survivors became blind as a result of corneal infections. It was known that those who survived smallpox were subsequently immune to the disease and, consequently, it was a common preventive practice to infect healthy individuals with smallpox by administering material taken from smallpox patients, a procedure called *variolation*. This practice might date back to the Ottoman Empire. However, variolation was not optimal as some variolated persons died from the resulting smallpox, infected others with smallpox, or died of other infections. Edward Jenner was interested in finding a better preventive method. He, as others before him, observed that dairy maids, the young women whose occupation was milking cows, developed a mild disease called cowpox, and that these women seemed to be immune during smallpox outbreaks. Jenner successfully vaccinated people using material from women who previously had cowpox.

It is very likely that Edward Jenner knew nothing about viruses. He is believed to have worked purely on observational data, even though the first-known publication on germ theory, *De Contaggione et Contagiosis Morbis*, had been written by Girolamo Fracastoro (1478–1553) in 1546. Fracastoro, a Venetian physician, proposed that epidemic diseases are caused by transferable tiny particles or 'spores', which could transmit infection by direct or indirect contact or even without contact over long distances. However, it was not until the end of the nineteenth century and with the help of microscopes that bacteria were identified as causes of infectious diseases, leading to the germ theory of disease as we know it today. *Ignaz Semmelweis* (1818–65), *Louis Pasteur* (1822–95), *Robert Koch* (1843–1910), and others developed the *germ theory*, marking a turning point in the thinking about diseases and public health in general.

FIGURE 1.7 John Graunt (1620–74)

Source: http://en.wikipedia.org/wiki/File:Graunt2.gif

The first serious attempt to count health-related events is ascribed to *John Graunt* (1620–74) (Graunt 1662). John Graunt was a haberdasher, a gentleman of London, and a Founding Fellow of the Royal Philosophical Society. He collected and analysed the Bills of Mortality, which were published weekly by the parish clerks of the City of London, to monitor the plague. Graunt's book

Natural and Political Observations Made upon the Bills of Mortality (1662) is seen as one of the very first publications on public health statistics.

Graunt observed that more males were born than females, females were more frequently sick, mortality was high among infants, and that seasonal fluctuations in mortality occurred. In his book, Graunt presented life tables for the first time and showed time trends for many diseases. Table 1.1 gives an example of John Graunt's analyses. With these types of statistics he was, for example, able to show that large population decreases during plague years were countered by increases in births in following years.

TABLE 1.1 Causes of death according to John Graunt

Time period	'Died or buried'	'Whereof plague'	Plague mortality proportion	Birth ('christened')	Death to birth ratios
1592	25 886	11 503	2 to 5	4277	6 to 1
1603	37 294	30 561	4 to 5	4784	8 to 1
1625	54 265	35 417	7 to 10	6983	8 to 1
1636	23 359	10 400	2 to 5	9522	5 to 2

Source: Morabia 2004

The British physician and statistician *William Farr* (1807–83) was the first Compiler of Abstracts in the General Register Office of England and Wales. Farr collected population statistics on births, deaths, and marriages. He is acknowledged as the father of *vital statistics* (see Chapter 6) and is considered as one of the founders of medical statistics. He is well-known for the construction of mathematical models to explain the natural history of epidemics and for his attempts to find 'laws of epidemics'. Farr, in England, in collaboration with Marc d'Espine in Switzerland, developed a nomenclature system for grouping diseases, which formed the basis for the International Classification of Diseases (ICD).The adoption of this classification by many countries to code causes of death recorded on death certificates greatly improved the comparability of international mortality statistics.

In 1754, *James Lind* stated that experiments were the most effective way of determining causal relationships between the environment and disease. He recommended that sailors should be in 'pure dry air' and should eat fruit and vegetables to prevent scurvy, which until then killed many English sailors. The Dutch had successfully adopted eating citrus 200 years earlier and, when the Royal Navy implemented citrus as a preventive treatment some 50 years after James Lind's recommendation, scurvy disappeared. James Lind's description of his experiment on board the HMS *Salisbury* is today considered to be the first description of an experimental study:

> I took twelve patients in the scurvy on board the Salisbury at sea. The cases were as similar as I could have them … they lay together in one place … and had one diet common to them all.
>
> Two of these were ordered a quart of cider a day. Two others took twenty-five gutts of elixir vitriol … Two others took two spoonfuls of vinegar … Two were put under a course of

> sea water … Two others had each two oranges and one lemon given to them each day … Two others took the bigness of a nutmeg.
>
> The most sudden and visible good effects were perceived from the use of oranges and lemon, one of those who had taken them being at the end of six days fit for duty … The other … was appointed nurse to the rest of the sick.
>
> *Source: Lind 1753*

In 1775, *Sir Percivall Pott*, an English surgeon, described the relationship between scrotal cancer in chimney sweeps and soot in his *Chirurgical Observations* (Rao et al. 2008). His work is now considered a milestone in occupational epidemiology. Pott was the first to attribute an occupational cause to cancer, raising the possibility of prevention. In his words:

> The fate of these people seems singularly hard; in their early infancy they are most frequently treated with great brutality, and almost starved with cold and hunger; they are thrust up narrow, and sometimes hot chimneys, where they are buried, burned and almost suffocated; and when they get to puberty, become liable to a most noisome, painful and fatal disease.
>
> *Source: Dos Santos Silva 1999*

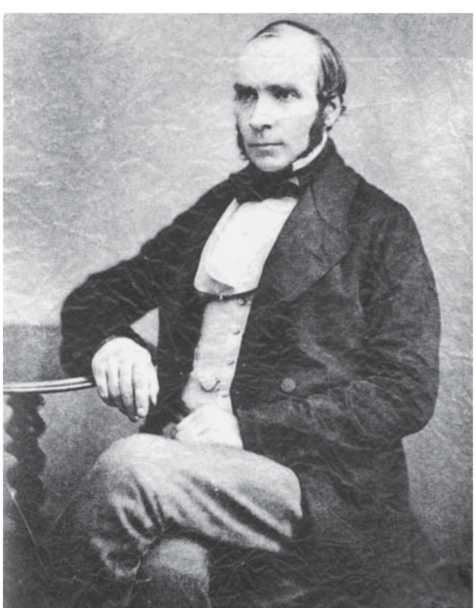
Pott's work was continued by *Sir Henry Butlin* (1845–1912), a surgeon at St Bartholomew's Hospital in London. Butlin made use of a 'natural experiment' to observe that protective clothing was associated with a reduction in the risk of scrotal cancer.

For many Western countries, the nineteenth century was characterised by increases in industrialisation and urbanisation, and, initially, mortality rates caused by infectious diseases were very high. The British lawyer *Sir Edwin Chadwick* (1800–90), concerned about the economic costs of ill health among the general public and influenced by liberal ideas, developed the 'sanitary idea' in 1832, when he proposed a technical solution to the 'miasma induced' diseases associated with poverty and overcrowding in London's slums. Public health was starting to be part of the social reform process. The English *Public Health Act* of 1848 legislated for the provision of clean water, sewers, and waste disposal services in order to address health problems (Hamlin & Sheard 1998). The Act is still seen today as one of most influential and imaginative public health legislations of all time.

It was around the same time, in the middle of the nineteenth century, when epidemiology received methodological inspiration from the work of *John Snow*, a London anaesthesiologist (Hempel 2006).

Snow is best known for his work on cholera and, in particular, for showing the link between an outbreak of the disease in London in 1845 and contaminated water supplies. He started his observations by carefully mapping the geographic distribution of the disease across the city, then adding the sources of water (supplied by two

FIGURE 1.8 Dr John Snow (1813–58), British physician



Source: http://en.wikipedia.org/wiki/File:John_Snow.jpg companies) to his map. As one of the companies supplied contaminated water, Snow found a way of testing his hypothesis purely by observation, without the need for conducting an experiment. His genuine contribution to epidemiology was that he did not limit himself to previously recorded data, but actually collected information to test his hypothesis. John Snow's study shows some classic hallmarks of modern analytical epidemiology:

» The study tested a hypothesis: contaminated water is the cause of cholera.

It is most important that a hypothesis is stated in a format that will allow it to be tested and refuted. That is, a hypothesis must be falsifiable for it to be useful in science (see Chapter 5 for more details). In modern epidemiology, the hypothesis is the centre of a study. The hypothesis should be plausible; however, a study is needed to test it. If it was known right from the beginning that a hypothesis is true, there would be no point in conducting a study. It would be an unethical waste of resources.

A hypothesis is an assumption, based on observation, knowledge, experience, or previous studies, which tries to explain a certain phenomenon.

» The study used a control group.

Comparing groups of people is a principal way of testing hypotheses in modern epidemiology. Snow's control group occurred naturally, as both companies supplied water to the same districts of London; some of his main results are listed in Table 1.2 (Snow 1855).

TABLE 1.2 Water supply and death from cholera (adapted from Snow 1855)

Water supply	Number of houses	Deaths from cholera	Deaths per 10 000 houses
Southwark & Vauxhall Company	40 046	1263	315
Lambeth Company	26 107	98	38
Rest of London	256 423	1422	56

» The study design controlled for bias.

Control of bias is an important issue in epidemiological research. In Snow's study, the two comparison groups (the residents of London being supplied water by two different companies) were as alike as possible in every way except for the source of water supply. Snow noted:

> … the intermixing of the water supply of the Southwark and Vauxhall Company with that of the Lambeth Company, over an extensive part of London, admitted of the subject being sifted in such a way as to yield the most incontrovertible proof on one side or the other. In the sub-districts enumerated in the above table as being supplied by both Companies, the mixing of the supply is of the most intimate kind. The pipes of each Company go down all the streets, and into nearly all the courts and alleys. A few houses are supplied by one Company and a few by the other, according to the decision of the owner or occupier at that time when the Companies were in active competition. In many cases a single house has a supply different from that on either side. Each Company supplies both rich and poor, both large houses and small, there is no difference either in the condition or occupation of the persons receiving the water of the different Companies. Now it must be evident that, if the diminution of cholera, in the districts partly supplied with the improved water, dependent on this supply, the houses

> receiving it would be the houses enjoying the whole benefit of the diminution of the malady, whilst the houses supplied with the water from Battersea Fields would suffer the same mortality as they would if the improved supply did not exist at all. As there is no difference whatever, either in the houses or the people receiving the supply of the two Water Companies, or in any of the physical conditions with which they are surrounded, it is obvious that no experiment could have been devised which would more thoroughly test the effects of water supply on the progress of cholera than this, which circumstances placed ready made before the observer.
>
> The experiment, too, was on the grandest scale. No fewer than three hundred thousand people of both sexes, of every age and occupation, and of every rank and station, from gentlefolks down to the very poor, were divided into two groups without their choice, and, in most cases, without their knowledge; one group being supplied with water containing the sewage of London, and, amongst it, whatever might have come from the cholera patients, the other group having water quite free from such impurity …
>
> *Source: Snow 1855*

The principles applied in the historical studies introduced above are summarised in the following. These principles are still guiding modern epidemiology.

» There are relationships between a person's environment and his/her disease experience (Hippocrates, 400 BCE).
» Counting events is a productive way of exploring these relationships (John Graunt, 1662).
» Prediction of future events based on counts of past events is possible (William Farr, 1850).
» Experiment is the most effective way of determining causal relationships between environment and health (James Lind, 1754).
» In the absence of deliberate experiment, there are things to be learnt from the observation of 'natural experiments' (John Snow, 1855).

With the *Public Health Act* introduced during the second half of the nineteenth century, epidemiology started to impact directly on public health legislation and services in the United Kingdom and the United States. Infectious diseases remained the focus of epidemiology until the early twentieth century, when *Dr Joseph Goldberger* (1874–1929), a physician and epidemiologist in the United States public health service, showed that pellagra was not infectious but caused by dietary deficiencies.

Modern epidemiology dawned with the work of *Sir Richard Doll* (1912–2005) (physiologist and epidemiologist) and *Sir Austin Bradford Hill* (1897–1991) (statistician and epidemiologist) in the United Kingdom, as well as that of *Ernst Ludwig Wynder* (1922–99) (epidemiologist) and *Evarts Graham* (1883–1957) (physician) in the United States. Doll and Hill, as well as Wynder and Graham, independently studied the relationship between cigarette smoking and lung cancer in the 1950s. Their works are widely seen as marking the start of 'modern epidemiology', although similar research using comparable methodology had been previously conducted in Nazi Germany. Both initial American and UK-based case–control studies clearly showed the detrimental effects of smoking (Doll & Hill 1950; Wynder & Graham 1950). Doll and Hill (1950) went on to confirm their initial findings by using a different study design. They wrote to a large number of British doctors and followed them by mail and official death records over subsequent decades to establish their causes of death. The British Doctors Study was a prospective cohort study (see Chapter 8) that ran from 1951 to 2001. Sir Richard Doll, who oversaw the study in its entirety, died in 2005, aged 92.

In 1960, 10 years after the publication of those key case–control studies, the very first comprehensive and widely influential textbook of epidemiology was published: *Epidemiologic Methods* by Brian MacMahon and Thomas Pugh, which was later reissued as *Epidemiology: Principles and Methods* (1970).

Examples of major achievements in public health through epidemiology

Over the last century, public health has claimed some very important victories over diseases that previously killed uncounted numbers of people. The control of communicable diseases can be seen as the most important contribution made by epidemiology to our global society. In the twentieth century, there was a rapid decrease in death rates from infectious diseases in developed countries due to the combination of improved sanitation and hygiene, successful vaccination programs, and the development of penicillin and other antimicrobial medications (CDC 1999), as shown in Figure 1.2. In 2000, the Centers for Disease Control and Prevention listed the 10 great public health achievements of the last century in the United States as: vaccination; motor vehicle safety; safer workplaces; control of infectious diseases; decline in death from coronary heart disease and stroke; safer and healthier foods; healthier mothers and babies; family planning; fluoridation of drinking water; and recognition of tobacco use as a health hazard (CDC 2000). Combined, these public health successes led to an estimated increase in life expectancy of about 25 years for people living in the United States (CDC 2000).

Some of the major public health achievements based on epidemiological research are highlighted below.

Eliminating smallpox

Smallpox is a contagious disease caused by the variola virus. Smallpox is believed to have originated more than 3000 years ago from India or Egypt as a consequence of the domestication of cattle. For centuries, smallpox was a major killer. Smallpox epidemics swept through countries and continents, killing up to 30% of infected people and severely debilitating survivors. Notably, native populations in the New World and Australia fell victim to smallpox during colonisation.

Edward Jenner's vaccine against smallpox, based on cowpox, which he developed in the late eighteenth century, provided the first reasons for hope. However, in early 1950 there were still an estimated 50 million cases of smallpox worldwide. When a 10-year eradication program was proposed in 1967, 10–15 million new cases and 2 million deaths were occurring annually in 31 countries. The last naturally occurring case of smallpox was reported in 1977. By 1979, smallpox was officially eradicated, thus improving the health and well-being of millions of people in many of the poorest countries in the world. The WHO coordinated the intensive campaign to eliminate smallpox (WHO 2010). Epidemiology played a central part in the eradication campaign by: providing information about the distribution of cases and the model, mechanisms, and levels of transmission; mapping outbreaks of the disease; and evaluating control measures.

Rheumatic fever and rheumatic heart disease

Rheumatic fever is caused by group A streptococcal infection. The fever affects children aged 5–15 years. *Rheumatic heart disease* is a possible consequence of rheumatic fever. Rheumatic fever and rheumatic heart disease are associated with poverty and, in particular, with poor housing and overcrowding, both of which favour the spread of streptococcal upper respiratory tract infections.

In many developed countries, such as the United States and Western Europe, the decline of rheumatic fever started at the beginning of the twentieth century, long before the introduction of effective drugs, such as sulfonamides and penicillin. The decline probably reflects improved socio-economic conditions and a fall in the prevalence of the rheumatogenic strains of group A streptococci (Wallace 2009). Today, apart from isolated outbreaks, the disease has almost disappeared from developed countries. However, pockets of relatively high incidence remain among socially and economically disadvantaged groups. In Australia, rheumatic fever is rare except among Aboriginal and Torres Strait Islander people who live in remote communities. In fact, a 2007 report showed that the world's highest rates of acute rheumatic fever and rheumatic heart disease were recorded in Indigenous people from central and northern Australia (Carapetis et al. 2007). Similarly, between 1996 and 2005, acute rheumatic fever declined among New Zealand's European inhabitants but increased in the Māori and Pacific Islander populations (Jaine et al. 2008). In many developing countries, rheumatic heart disease is one of the most common forms of heart disease.

Epidemiology has contributed to our understanding of the causes of rheumatic fever and rheumatic heart disease, and the development of preventive methods. Epidemiological studies have highlighted social and economic factors that contribute to outbreaks of rheumatic fever.

Iodine deficiency

Iodine deficiency causes loss of physical and mental energy associated with inadequate production of the iodine-containing thyroid hormone. Iodine deficiency is the single most common cause of preventable mental retardation; it decreases childhood survival, causes goitres, and impairs growth and development (International Council for the Control of Iodine Deficiency Disorders 2010).

Prior to 1922, when prophylaxis was introduced, 0.5% of people were cretins and almost 100% of school children had large goitres in some regions of Switzerland (Burgi et al. 1990). In 1922, Switzerland introduced iodisation of salt and after 1930 no new cretins were born and goitre in children disappeared. Marine and Kimball conducted the first large-scale studies of goitre in Akron, Ohio, among 2100 school children. The results of their studies were unequivocal, and they concluded that goitre '… is as easily prevented in humans as it is in fish or in domestic animals' (Zimmermann 2008). The prophylactic effects were indeed impressive and iodised salt was introduced in Michigan, in the United States, in 1924.

Until the 1980s, iodine deficiency was not part of public health programs. Controlled studies, however, showed that iodine supplementation not only eliminated cretinism but also improved cognitive function. Hence, it was recognised that iodine deficiency had a potentially far-reaching social and economic impact on a society. It was estimated that iodine deficiency affected about 1.5 billion people, mostly in developing countries (Hetzel 2004). Many public health programs have routinely included iodine deficiency elimination strategies since the 1990s.

Smoking and lung cancer

Lung cancer used to be rare and was not even recognised as a disease until 1761. However, its incidence began to increase together with the increase in *smoking* until, in 2002, lung cancer was the most frequent cancer on earth, affecting 1.35 million people (Parkin et al. 2005).

Apart from research conducted in Nazi Germany by Franz Mueller and Eberhard Schairer, the first epidemiological studies linking smoking to lung cancer were published in the 1950s by Doll and Hill, and Wynder and Graham, with their results being subsequently confirmed by numerous studies. Many substances capable of causing cancer have been identified in tobacco smoke, and it is now clear that the main cause of the increase in lung cancer death rates is tobacco smoking. However, there are also other causes of lung cancer, such as asbestos, dust, and air pollution. Epidemiological studies were able to show that smoking and exposure to asbestos interact, creating exceedingly high lung cancer rates among asbestos workers who smoke (Hammond et al. 1979, see Table 1.3).

TABLE 1.3 Age-standardised lung cancer death rates per 100 000 population stratified by smoking habits and exposure to asbestos

History of smoking	Exposure to asbestos	Lung cancer death rate per 100 000
No	No	11
No	Yes	58
Yes	No	123
Yes	Yes	602

Source: Hammond et al. 1979

The examples of public health interventions based on epidemiological studies discussed so far are just a small selection of the countless available success stories. For instance, more recently, epidemiological studies have helped to identify: sun exposure as the environmental risk factor for skin cancer; human papilloma virus as a cause of cervical cancer; a preventive role for fluoride in drinking water against dental caries; aspirin as a treatment or preventive therapy for myocardial infarction; the role of supplementation with folic acid in the prevention of oral clefts; and genetic mutations, such as *BRAC1* and *BRAC2*, as risk factors for breast cancer. The recent report of the Global Polio Eradication Initiative celebrated the success of poliomyelitis eradication for the WHO South-East Asia Region as one of the world's great achievements in global health (WHO 2014).

Evidence-based practice

Another example of public health achievements based on epidemiologic research and principles is the evidence-base practice (EBP) movement, which gained momentum in the 1990s and is linked closely to David Sackett, Archie Cochrane, and others (see Chapter 5). EBP implies that practical clinical decisions should be based on the current and best evidence available. As a consequence of the EBP movement, conduct and reporting of research in clinical epidemiology were standardised and improved, which led to more transparency and better patient outcomes. As health professionals, you are nowadays expected to be able to critically appraise the available evidence so you can work in an evidence-based way; this book provides you with the tools to do just that.

The successes achieved so far also highlight the need for continued epidemiological investigation and public health measures, as deficits, especially in developing countries and in socially disadvantaged Indigenous populations, are obvious.

SUMMARY

- Epidemiology is the study of the distribution and determinants of health-related states or events in specified populations, and the application of this study to the control of health problems.
- Epidemiological studies can be classified into qualitative and quantitative research. Quantitative research is further differentiated into descriptive and comparative types. Comparative analytical studies are either experimental or purely observational in nature.
- Research is an organised quest for new knowledge. The scientific method delivers guidelines for the way to conduct research. Epidemiology is the scientific method used in public health.
- At the core of an epidemiological study is the research hypothesis. This hypothesis has to be falsifiable.
- The epidemiological process is a cycle that starts with a literature review. The research idea is translated into a falsifiable hypothesis, which takes the study design into account. Data are collected in a standardised manner and analysed using statistical tools. Resulting new knowledge is published.
- Historically, epidemiology has achieved major successes, but there is still much room for further epidemiological research and resulting evidence-based public health measures, especially in the developing world and in Indigenous populations.

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WEBSITES

http://en.wikipedia.org/wiki/Scientific_method

An easy-to-access source for further details about the men and women who shaped the history of epidemiology can be found by going to http://en.wikipedia.org/wiki/ and entering as search terms the names of the mentioned key individuals (e.g. 'Hippocrates', 'Edward Jenner'). You will find numerous original sources in the references to the sites. More details and links to numerous books on the scientific method can be found at the link above.

www.cdc.gov/about/history/tengpha.htm

If you are interested in the history of public health and its success stories, the websites hosted by the United States Centers for Disease Control and Prevention, and the linked Morbidity and Mortality Weekly Reports, are a must-read.

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ANSWERS TO CRITICAL THINKING EXERCISES

Exercise 1.1

(a) Epidemic: An epidemic is an outbreak of an infectious (and nowadays also chronic) disease beyond the case numbers that are usually expected in a specific place (e.g. country) over a specific time period (e.g. month or year). For example, New Zealand fought a campylobacteriosis epidemic with a notification rate of 400 per 100 000 inhabitants in May 2006. The main source of human infection is fresh chicken (Baker et al. 2006).

(b) Endemic means that a disease is 'always in the place'. For example, the virus for the common flu (influenza) is in the Australian and New Zealand population all year round and at any time during a year some people will have the flu ('endemic'). However, only during the winter months is the frequency of the common flu high ('epidemic').

(c) Epidemiology is the study of the distribution and determinants of health-related states or events in specified populations, and the application of this study to the control of health problems. In other words, epidemiology studies the distribution and the risk factors of diseases, and the results of these studies are used to manage diseases.

Exercise 1.2

Examples would include all infectious diseases that do not usually occur in Australia or New Zealand, such as malaria, avian influenza (bird flu), typhoid, Ebola virus disease or cholera. Isolated cases of these diseases might occur in Australia or New Zealand due, for example, to travel or contact with people from countries where they are endemic. In 2007, an outbreak of cholera was described in Sydney: three elderly female Sydney residents were diagnosed with *Vibrio cholerae* infections. The outbreak was traced back to raw imported whitebait. It was the first recorded outbreak of cholera in Australia for more than 30 years (Forssman et al. 2007).

Exercise 1.3

» Description of natural history of disease: This is the description of the development of a disease from its initial occurrence in an individual to recovery, disability, or death. Examples: (1) HIV/AIDS: infection with HIV, development of symptoms, diagnosis of AIDS, treatment with antiretroviral drugs, death. (2) Colorectal cancer: a combination of known and unknown factors cause cancer in a susceptible person, development of cancer, symptoms, diagnosis of cancer, treatment, recovery or death.

» Description of the health status of a population (disease burden in community): This is the description of disease occurrence or health status in a population often by characteristics of persons, place, and time. Examples: (1) Occurrence of obesity in Australian children in 2010. (2) Changes in the occurrence of dementia in elderly residents in Auckland, New Zealand, between 1980 and 2010.

» Identification of causes of disease (disease aetiology): 'What are the causes of a disease?' is one of the central questions that epidemiology tries to address. Examples: (1) The necessary cause for AIDS is being infected with HIV. (2) Another cause for AIDS in drug users is needle-sharing. However, needle-sharing alone will not cause AIDS unless the needles harbour the virus. As you can see from this example, there are different levels of causality. This issue is further discussed in Chapter 2.

» Explaining local disease occurrence (e.g. outbreak of infectious disease): Explaining local disease occurrence is a mixture of describing disease occurrence and identifying causes of disease occurrence. Examples: (1) The work on cholera by John Snow is an example of explaining local disease occurrence. Snow described the distribution of cholera in London; based on this distribution he formulated and tested a hypothesis; he identified contaminated water as the cause of the cholera outbreak and could, thus, explain the outbreak. (2) This aim also covers the epidemiological efforts to predict the development of outbreaks or epidemics, for example, studies which predict the spread of H1N1 (swine flu) in a community.

» Identification of prognostic factors (factors influencing survival): Epidemiology is also concerned with predicting survival of patients after diagnosis or treatment. For example, studies that identify prognostic factors for patients with cancer.

» Identification of 'best' treatment (therapeutic trials): All therapeutical trials are examples of this aim of epidemiology.

» Preventing disease and the evaluation of preventive measures. Examples: (1) 'Slip, slop, slap' campaign in Australia to prevent skin cancer. (2) Screening for cervical cancer. (3) Tobacco control efforts. (4) Vaccination programs.

» Evaluation of health-related programs and health services. Examples: (1) Evaluation of screening programs for breast cancer. (2) Assessment of the cost-effectiveness of the public hospitals in Western Australia.

» Guiding administrators of health services and legislators in their decision-making process. Distinguished epidemiologists may be asked to take on the role of advisors to the government in health matters. Legislation (e.g. with respect to smoking in public places) is guided and influenced by results from epidemiological studies.

Exercise 1.4

(a) A study investigated the occurrence of trachoma in an Indigenous community in Australia. The frequency of trachoma was presented for the community.

This study was a quantitative descriptive study—only the occurrence of trachoma was described.

(b) A study investigated the agreement between assessors of photographs of the tarsus used for trachoma grading.

This study was a quantitative comparative quality control research study. The quality of a tool (the photographs) was assessed for its further use in research.

(c) A study investigated risk factors for trachoma in Indigenous Australian children. A group of children with trachoma was compared to a group of children without trachoma with respect to living conditions and hygienic behaviours of the families.

This study was a quantitative comparative observational study. The investigated exposures were living conditions and hygienic behaviours; these exposures were not changed or varied by the investigators but merely observed.

(d) A study investigated whether an educational program on facial cleanliness and hygienic procedures for Indigenous Australian parents can reduce the occurrence of trachoma in children.

The educational program was implemented in one community and results were compared to those in a similar community, which did not receive the intervention.

This study was a quantitative comparative experimental study. The intervention was the educational program and the program was actively administered by the researchers: one community received the intervention and another one did not.

Exercise 1.5

This comparative study (one group with education compared to another group without education = standard care) is an experimental study—it is a therapeutical trial to prevent malnutrition. The intervention (= study factor) is a nutritional education program, which was rolled out in some nursing homes but not in others (= control group). Hence, the researchers actively managed the intervention.

Exercise 1.6

This comparative study is an experimental study—a therapeutical trial for overweight and obesity. The intervention is an active video game upgrade, which is given to some children but not to others (= control group). Thus, the researchers deliberately administer (i.e. manage) the intervention (= study factor).

Exercise 1.7

From the literature we know that obesity in children is rising in many developed countries. In order to conduct research in an Australian setting, we start with a comprehensive literature review. We also talk to colleagues and we may listen to conference presentations on the topic. Based on this information, we develop a research idea, such as obesity is a problem in Australian children. We decide on the study design for the research; we want to describe the problem of obesity in Australian children, so a descriptive design will be applied. We decide to examine 6–10-year-old school children at schools in New South Wales and Victoria. We formulate our operational research hypothesis: 'The prevalence of obesity in Australian children aged 6 to 10 years is between 12.5% and 17.5%'. We develop a questionnaire that allows us to collect the relevant information in a standardised manner. We collect the data at selected schools. We may collect information on age and gender of the children in addition to their height and weight. The required sample size of schools and children can be statistically calculated; the size is dependent on our research hypothesis and in this specific case on the precision with which we would like to estimate the prevalence of obesity. We enter the data into a database and analyse it statistically. Our result is related back to the research hypothesis. We come to a research conclusion and we write a publication to ensure that this newly acquired knowledge can be accessed by everybody who is interested.