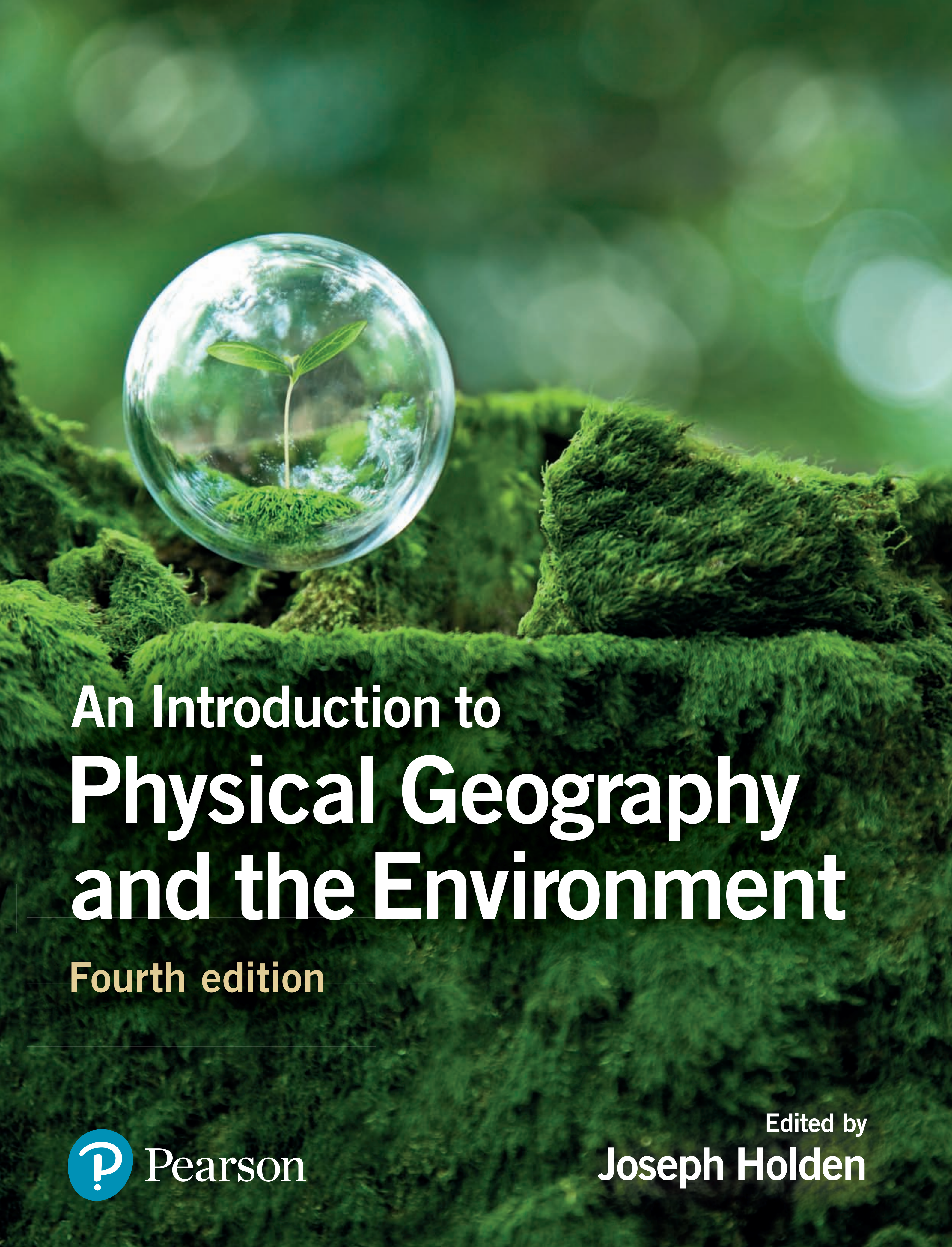

An Introduction to Physical Geography and the Environment

Fourth edition

Edited by
Joseph Holden

Pearson

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Physical Geography and the Environment

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PREFACE TO THE FOURTH EDITION

It is exciting being a physical geographer because you learn about environments around the world, how they function, and why they are shaped the way they are. Through this understanding we can see how humans have impacted the Earth and how human activities are influenced by environmental processes. Our understanding of the world is rapidly changing and I am continually amazed at the new discoveries that are made about how the world works.

This new edition provides chapters from 21 contributors who are all international experts in their field. Each of the chapters covers a wide range of material including core principles of the subject as well as new findings from ongoing research.The chapters are fully illustrated using diagrams and photographs from environments around the world. Between them, the contributors have researched in detail every environment on the planet. The chapters provide an unrivalled source of rich information from around the world for all budding physical geographers.

The book seeks to help you understand geographical processes and tackles the interlinkages between processes, places and environments. I hope that the book engages and inspires you and makes you ask new questions about the physical environment. I encourage you to use your geographical skills to seek answers to those questions and to share your discoveries with others.

Scope of the book

Physical geography is of wide interest and immense importance. It deals with the processes associated with climate, landforms, oceans and ecosystems of the world. The Earth has always been subject to changes in these systems and studying physical geography allows us to understand how Earth systems have come to operate as they do today. It also provides us with insights into how they may operate in the future. The impacts that humans have made on the Earth's environments are ever increasing as the world's population approaches eight billion. Thus the Earth's systems will change in the future both naturally and in a forced way through human action. However, it will be crucial to understand, manage and cope with such change and this can be achieved only by understanding the processes of physical geography. This text is aimed at those embarking on a university course and provides an introduction to the major subjects of physical geography.

The book provides a baseline of understanding and additionally it directs the reader to resources that encourage them to develop their studies further and has materials that should be of value throughout a university degree.

Tools used in the book

In addition to providing a rich source of information, the book uses a number of educational tools to aid understanding:

- The book is split into six parts, each with a **part opener** that describes the main themes of that part of the book and the links between the chapters within that part.
- **Learning objectives** clearly outline the purpose and aims of a particular chapter to help locate the reader within the book.
- **Boxed features** explore and illustrate topics and concepts through real-world examples. Scattered throughout every chapter, these insightful applications are differentiated into the following types:
  - case studies;
  - fundamental principles;
  - techniques;
  - hazards;
  - new directions.
- **Reflective questions** invite the reader to think about, and further explore, what they have just read. Useful for consolidating learning, these questions are found at the end of each major section of every chapter.
- A **summary** draws together the key ideas of the chapter, reflecting the learning objectives for that chapter.
- An **annotated list** of five further readings aims to inspire and enable deeper exploration into a topic. The reading lists include important papers as well as textbooks. Longer lists of further reading for each chapter are found on the companion website.
- The **comprehensive glossary** serves as an additional resource to help clarify concepts discussed within the book. Key words defined in the glossary are highlighted in the text the first time they appear in each chapter.

Companion website

The book also has a dedicated **website** at www.pearsoned.co.uk/holden on which there is a suite of other educational resources for both students and lecturers alike.

Lecturer resources

These contain:

- **PowerPoint slides:** a set of slides for every chapter comprising bulleted outlines of core topics and the key figures and images from the main text.
- **Field exercise ideas:** suggestions for activities that can be done in the field.

Student resources

These contain:

- **Multiple-choice questions:** a set of interactive questions for every chapter that allow students to test and consolidate their understanding.
- **Further reading:** an annotated list of further reading material for each chapter.
- **Annotated weblinks:** several hundred annotated additional websites for students to further explore a topic. There are weblinks listed for each chapter.
- **Interactive models for practical learning:** these models give students the opportunity to explore and understand environmental processes and the principles of modelling.

I hope that you are able to use the rich interactive resources that this book provides to further your learning and exploration of the subject of physical geography and the environment.

Joseph Holden
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Maps

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PART I

The role of physical geography

Figure PI.1 Physical geographers often collect samples and take measurements from instruments. However, there has to be a justification for taking such measurements and so one should start with a question or hypothesis that data collection in the field, laboratory or numerical model then tries to answer or test.

Part contents

Scope

Scientific disciplines are constantly evolving, adopting new approaches and techniques and moving into previously unthought-of areas. Part I contains a chapter which deals with the development of physical geography as a subject and the sorts of general approaches adopted by physical geographers to understand how the world works. The chapter provides context that explains why we approach the subject in particular ways today. It describes the basic frameworks for studying science and explains the roles of data collection from the natural environment, laboratory work and modelling. It describes the advantages and disadvantages of a range of approaches that we should be aware of when studying physical geography. It therefore sets the scene for the rest of the book by providing the reader with an appropriate grounding in the nature of the subject.

What do we mean by physical geography?

Physical geography is about understanding interactions of processes involving the Earth's climate system, oceans, landforms, animals, plants and people. This understanding requires linking the physical systems together and relating human actions to the physical environment. Of interest to physical geographers are the mechanisms that maintain flows of energy and matter across the Earth. There are components of study which include processes associated with plate tectonics, geomorphology, climatology, glaciology and hydrology that shape the surface of the Earth; the collection of climatic and atmospheric processes acting as one of the ultimate controls on the landscape and biosphere; and the ecological and biogeographical patterns that characterize the living portion of the Earth. Physical geography involves the application of technology to study these components and changes within them. For example, remote sensing from space provides an aid to monitoring the world's constantly changing natural and human landscapes, the oceans, atmosphere and biosphere.

Geographers often say that they study the 'why of where'. By this they mean that they seek to explain the underlying processes that result in the patterns of natural phenomena and the ways in which humans interact with, and alter, these processes and patterns. In addition to a spatial context, change over time is also a central theme to physical geography.

It is important to be aware of the ways in which physical geographers study physical geography. Some kind of theoretical basis of enquiry is essential in order to allow fair comparisons of results and interpretation of conclusions between different research areas. The scientific methods discussed in Chapter 1 help to form this philosophical foundation. The underlying method does not necessarily mean that all research is done using the same techniques; indeed physical geography utilizes a variety of tools to help understand, measure, observe and predict environmental processes. However, by maintaining a philosophical basis, it reminds us to question the approach we take. In recent years, emphasis has shifted from a position where science represents the ultimate authority informing society, to a realization that science is itself influenced by society, and that many other sources of knowledge must be equally considered. Consideration of the advantages and limitations of a given approach is therefore vital so that we can assess the reliability and usefulness of the conclusions attained.

CHAPTER 1

Approaching physical geography

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Learning objectives

After reading this chapter you should be able to:

- **describe the historical development of physical geography as a subject**
- **understand basic scientific methods**
- **evaluate methods for different types of research in physical geography**
- **appreciate the advantages and limitations of different approaches to physical geography**

1.1 Introduction

The physical environment affects most aspects of our daily lives. It is fundamental to human existence. For example, it determines water availability and water quality, weather and climate, soil systems, potential for agriculture, the risk of landslides or other hazards, and if and how we can travel from one place to the next. Physical geography involves the study of the interconnected features of the Earth (Figure 1.1). It deals with the Earth's climate system, which results from a combination of atmospheric, oceanic, land, ice and ecological processes. It also deals with a wide range of processes that affect the landscape of the Earth. For example, plate tectonic processes are responsible for mountain building, the movement of the continents, ocean floor spreading, ecological isolation and changing climate. In addition, the landscape is worn down by weathering and erosion processes, many of which are driven by gravity and water (in solid, liquid and gas form). Water also transports nutrients from soils to plants and from rocks and soils to rivers and into the oceans. It transports nutrients and energy around the globe through the oceans and the atmosphere. It moves sediments across hillslopes, catchments and seas. Understanding the variety of processes that link the components shown in Figure 1.1 (atmosphere, oceans, landforms and biosphere) at global and small scales enables improved prediction of future change of the Earth's environmental systems.

A range of tools are available to physical geographers in order to help us understand, measure, observe and predict environmental processes. These include tried and tested methods along with new technologies such as advanced probes and laboratory methods or geophysical and remote sensing tools that allow us to measure the Earth's features and processes remotely. For example, after spending a few minutes taking a series of photographs from slightly different locations around a feature such as a gully, a gravel river bank, a tree or a building it

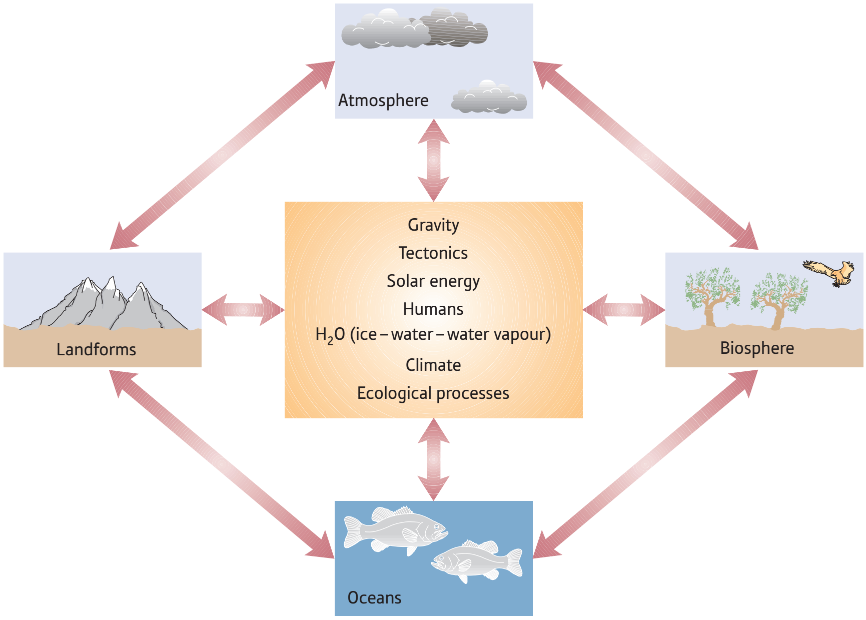

Figure 1.1 Components of the changing environment. The atmosphere, oceans, biosphere and landforms all interact with each other. Important links within the system include H_2O in its different forms, tectonics, ecological processes and humans.

is possible to use freely available Structure from Motion software to produce a 3D image on a computer of the feature and from this image it is possible to measure the dimensions of the feature in high resolution (e.g. to the nearest millimetre) (see Chapter 25). This sort of approach can save a lot of time undertaking painstaking field survey measurements, and has an almost infinite range of applications. Another example might be the growing use of 'flux towers' (Figure 1.2), which are ground-based instruments that can measure the net release or uptake of carbon dioxide (CO_2), methane, water vapour or energy across a sampling area such as a large field or a section of forest. These devices may take measurements every second and can be used to tell us whether the landscape is acting as a net sink or a net source of carbon to the atmosphere and also how this varies over days, months and years.

Field study, remote sensing, laboratory work and numerical modelling are all important components of the method of physical geography today. However, each particular approach and method has its limitations. No matter what type of measurement device or approach is used, it is often how it is used and why it is being used in those ways which are important. In other words, scientific approaches have a philosophical underpinning which can be evaluated. There are a range of approaches to science and physical geography and each approach has advantages and disadvantages. It is therefore necessary to understand these methods and their limitations so that we can: (i) evaluate which are the most appropriate methods to use for a given environmental investigation and (ii) fully evaluate the implications of any given research finding in physical geography.

The approaches that physical geographers have used have varied through time as the subject has developed.

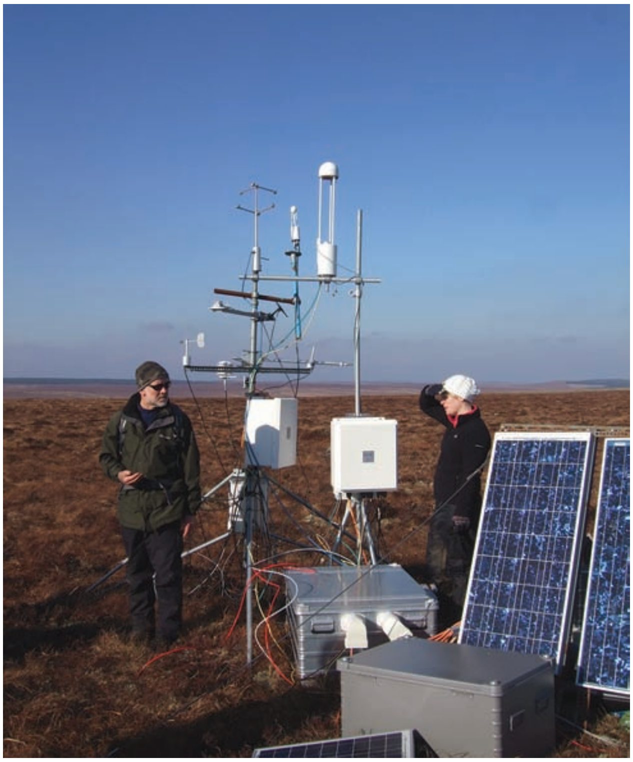

Figure 1.2 A flux tower on a peatland which can be left to run automatically. The instruments on the tower are used for measuring the uptake and release by the landscape of CO_2, energy and water vapour.

In order to understand contemporary practice in physical geography it is therefore necessary to know something about the history and development of the subject. This chapter will briefly describe the way physical geography has developed. It will then move on to discuss how the scientific method has been applied by physical geographers to studies of the environment. The remaining parts of the chapter will look at the principles of and approaches to (i) data collection from the environment, (ii) laboratory research and (iii) numerical modelling, all of which are important methods of physical geography.

1.2 Historical development of physical geography

1.2.1 Physical geography before 1800

The ancient Greeks were interested in the shape and topography of the Earth. Aristotle (~384–322 BC) logically demonstrated using evidence from lunar eclipses (when the Earth's shadow blocks the Sun's light from reaching the Moon) that the Earth was probably spherical. Eratosthenes (~276–195 BC), known as the 'Father of Geography', developed models of the Earth using parallels and meridians and using surveying techniques to determine the circumference of the Earth with amazing accuracy compared to today's satellite measurements. This Greek learning was also passed to Roman geographers, who produced maps and topographic descriptions of places and their history, supporting military expansion, and they also had a philosophical interest in the relations between humans and the environment.

Between the time of the Roman Empire and the sixteenth century, European science progressed very slowly. Often scholars rejected anything that seemed to go against the teachings of the Christian Church. In the Middle East, however, Arab geographers such as Al Muqaddasi (who lived between AD 945 and 988) were pioneering fieldwork whereby observations were given precedence. Indeed Al Muqaddasi stated that he would not present anything unless he had seen it with his own eyes. Such Arab geographers maintained the Greek and Roman techniques and developed new ones. Arab traders travelled throughout Asia, Africa and the Indian Ocean and added a great deal of geographical knowledge to update the classical sources. Any European geographical work was trivial in comparison with the huge amount published by Islamic writers of the Middle Ages. Exploration and learning also flourished in China with advanced triangulation techniques allowing exceptionally good quality maps of the region to be produced from the first century AD onwards. For the last 2000 years many official Chinese historical texts have contained a geographical section, which was often an enormous compilation of changes in placenames and local administrative divisions controlled by the ruling dynasty, descriptions of mountain ranges, river systems, taxable products and so on.

While science was slow to progress in Europe before the sixteenth century, with the **Renaissance** (~1400–1600 AD) came a renewed interest in the geographical knowledge of the ancients (which the Arab and Chinese scientists had already advanced significantly) and a willingness to test and refine their theories. The European explorations of the fifteenth and sixteenth centuries were part of a major period of invention and discovery. Improvements in measuring devices such as timekeepers and in mapping and printing techniques were combined with a new geographical knowledge about the world. Indeed many of these new technologies had roots in the pursuit of geographical knowledge. For example, methods for accurately keeping time were developed when stable navigation systems that could determine the longitude (east–west position) of a ship were invented. As the Earth is constantly rotating, knowing the time while making an altitude measurement to a known star or the Sun provided data to accurately calculate longitude. The experiences of the explorers had begun to overturn traditional views of those thought to be authority figures (such as leaders of the Christian Church and the theories of the ancient Greeks). For example, new continents were being discovered and the layout of land masses across the Earth was being determined. A fundamental importance (as recognized much earlier by Al Muqaddasi) was beginning to be placed on the role of real-world experience. This meant that determining whether or not there was a Southern Ocean land mass could only be established through experience and not by just reading the works of Aristotle. The importance of experience over authority was a central theme of the development of science during this period. However, it was because geography was inextricably linked to exploration, patriotism and colonization that it was considered an important subject by the society of the time. Geographers were making the key advances in discovering new lands, mapping them, changing people's perception of the shape and size of features of the Earth and bringing potential 'wealth' to nations that conquered and colonized others.

1.2.2 Physical geography between 1800 and 1950

1.2.2.1 Uniformitarianism

Prior to the early nineteenth century the prevailing belief of the western world had been that the Earth was created in 4004 BC. The landscapes of the Earth were thought to be a result of catastrophic events. For example, it was thought that river valleys were scoured out during the biblical flood and that peatlands were remnants of the slime left behind after the flood receded. However, the increasing scientific knowledge acquired between the sixteenth and the end of the nineteenth centuries began to lead to different views developing. One new idea that emerged, for example, was that the Earth's landscapes gradually changed over time rather than simply being affected by one or two sudden catastrophic events. Turner (1757), for example, showed that if you dug a small hole in a peatland, new peat would form in the hole after a few years thereby showing that peat was not the detritus left behind from a major flood. One of the most persistent and influential themes to affect physical geography and especially geomorphology was the *Theory of the Earth* published by James Hutton in 1795 and clarified by Playfair (1802) in his *Illustrations of the Huttonian theory of the Earth*. Hutton and Playfair were scientists who examined the Earth's landscapes and tried to understand their formation. Hutton's theory rejected catastrophic forces as the explanation for environmental features and gave rise to a school of thought known as **uniformitarianism** (Gregory, 1985). The central component of this concept is that present-day processes that we can observe should be used to inform our understanding of past processes that we cannot observe. In other words, many of the processes we can see today are probably the same as those that occurred in the past and so we can infer what went on in the past from understanding contemporary environmental processes. Uniformitarianism propagated the idea that 'the present is the key to the past'. Although this idea was very satisfactory in terms of the processes for understanding the past, of course it cannot be assumed that the rates at which processes operate today (e.g. weathering of rock) are the same as those that occurred in the past. Nevertheless it was still recognized that given enough time a stream could carve a valley, ice could erode rock, and sediment could accumulate and form new landforms. Hutton speculated that millions of years would have been required to shape the Earth into its contemporary form. It was not until the early 1900s and the discovery of radioactivity that estimates of the age of the Earth became more reliable. Radioactive elements such as uranium and strontium are unstable and decay at a steady rate. Uranium-238, for example, decays into lead-206. Comparing the ratio of these two elements allows us to determine how much time has passed since the uranium sample was pure when the rock solidified. Radioactive decay also gives off heat and we can determine the rate of Earth cooling to determine a time when it formed. The Earth is in fact around 4.6 billion years old. The oldest rocks that have been found on the Earth date to about 3.9 billion years ago.

1.2.2.2 Darwin, Davis and Gilbert

Charles Darwin was a brilliant scientist who collected and organized specimens. He read some of the writings on uniformitarianism and extended these ideas to biology. The theory of evolution suggests that the diversity of species occurs due to continuous, slow modifications to genetic traits over very long periods of time. Darwin's *The Origin of Species* published in 1859 was hugely influential in the field of science and in society in general. Indeed it has often been referred to as the 'book that shook the world'. The book outlined how there could be a relatively gradual change in the characteristics of successive generations of a species and that higher plants and animals evolved slowly over time from lower beings. This evolution occurred as a result of competition within local interacting communities (see Chapters 10–12). Darwin's book helped throw the idea that there was a complete difference between humans and the animal world into turmoil as he reinforced the suggestion that humans evolved from lower beings. With the idea that humans could have evolved from lower beings came the undermining of traditional religious opinions. However, although some religious leaders did embrace Darwinism at the time, the theories were very different from those that had come before. These ideas radically shook a society where, because of the increasing availability of printed books and papers, intellectual knowledge was being transferred in greater quantity than ever before.

Darwin's ideas influenced most areas of science at the time. The idea of 'change through time' was reflected in evolutionary attitudes to the study of landforms following Darwin's own 1842 study of the evolution of coral islands which was particularly influential in relation to the 'cycle of erosion' idea promoted by W.M. Davis (Gregory, 1985). The approach recommended by Davis, who was a very revered geomorphologist, dominated approaches to physical geography from the late nineteenth century through until the 1950s. Davis suggested in 1889 that the normal cycle of erosion could be used to classify any landscape according to the stage that it had reached in the erosion cycle. He termed this the 'cycle of life', which was a rather biological metaphor for landform development. Figure 1.3 shows the **Davisian cycles of erosion**. A youthful uplifted landscape begins to be dissected by rivers. As the landscape matures these valleys become wider and more gently sloping until eventually all that remains is a flat, old landscape (a **peneplain**). The great success of the Davisian approach, dominating popular physical geography for 60 years, was due to the fact that it was simple and could easily be applied by people to a wide range of landscapes. As a result of these ideas people then tried to determine the history of an area by establishing which stage of the Davisian cycle it was in. This approach was also known as **denudation chronology**. While Davis had based his ideas on the case study of the Appalachians in the United States,

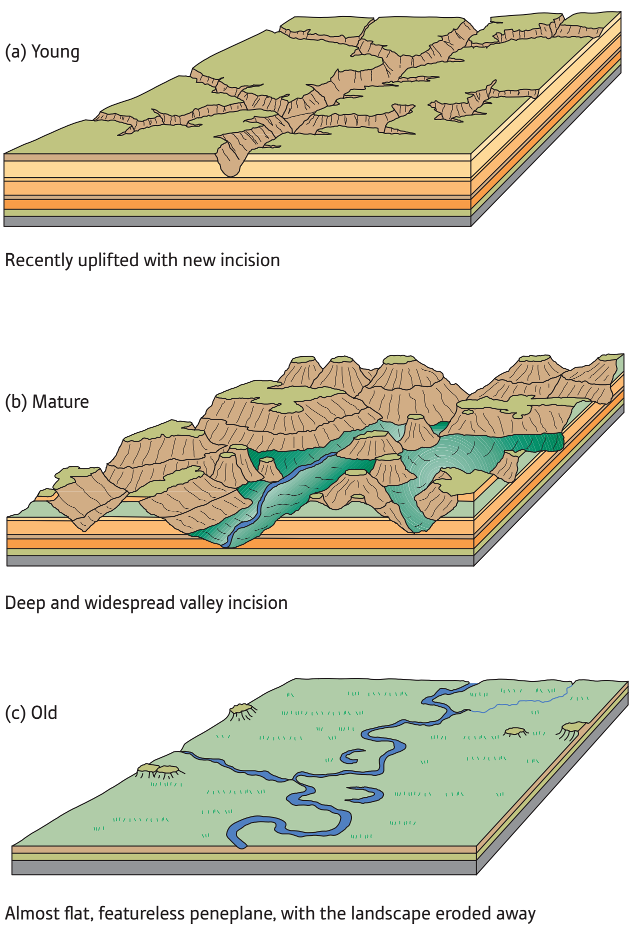

Figure 1.3 The Davisian cycles of erosion: (a) young uplifted stage with very limited incision; (b) a mature stage with deep valley incision and complex topography; (c) an old eroded landscape with few topographic features. (Source: after Davis, 1889)

the Davisian ideas were applied by many to help interpret landscapes across the globe (e.g. Cotton, 1922, applied the ideas to parts of New Zealand and Wooldridge and Linton, 1939, produced a Davisian interpretation of south-east England). In plant geography and ecology a similar influence was being expressed by Clements (1916, 1928) in his concept of succession (see Section 11.4.3 in Chapter 11). It is notable, however, that two themes of Darwin's work ((i) struggle and selection; (ii) randomness and chance) did not have an immediate impact on physical geography (Stoddard, 1966). Indeed the unique contribution of Darwin's theory, which was 'random variation' whereby random change could occur to species from one generation to the next, did not really appear in work by physical geographers until the 1960s (Gregory, 1985). Nevertheless the theme of evolution provided an historical perspective to physical geography which still dominates geomorphology, studies of soils, biogeography and climatology.

An alternative approach that was advocated at the same time as the Davisian approach was that of G.K. Gilbert. Gilbert, an explorer of the American West, wanted to understand *why* particular landforms developed rather than just classify them as being youthful or mature. In order to understand landform development he recognized the importance of describing physical processes and deriving systems of laws that determined how a landform could change. He attempted to apply quantitative methods to geological investigations. His ideas, however, were not taken on board during an era dominated by the descriptive techniques offered by Davis. It was not until the 1950s that physical geography came to revisit his approach and that Gilbert's ideas finally won favour. Until the 1950s, therefore, physical geography was largely descriptive and was concerned with regions. It was concerned with the evolution of environments and their classification. There were virtually no measurements of environmental processes involved and if you look at geography books from that period you will see that they are structured by regions and simply describe regional climates, landscapes, resources and trade (e.g. L. Dudley Stamp's 1949 book *The world: A general geography*).

1.2.2.3 Divisions of physical geography

The early twentieth century saw a number of advances which resulted in identifiable branches in physical geography being developed. Davis and Gilbert helped form the field of geomorphology, while Russian scientists such as Dokuchaev formed the study of soils (pedology) showing how soil types could be related to climate, underlying materials and shape of the landscape. The branches of climatology and meteorology were beginning to be established, accelerated with the development of the aeroplane and emergent war needs. Researchers such as Clements helped establish biogeographical concepts such as **succession** which enabled ecology–human interaction studies to expand. Broadly, the above fields are still those studied today within the discipline, although the subject of physical geography is ever evolving and there are many interactions between these areas. Some physical geography departments, for example, will form groups around 'biogeoscience' dealing with biological and chemical processes and transfers in the water, land, atmosphere and biosphere system.

1.2.3 Physical geography since 1950

1.2.3.1 The quantitative revolution

In the 1950s, European and North American geography was forced to change. It was realized that describing places and putting boundaries around them, where in fact real boundaries did not actually exist, was no longer a useful approach. The 1950s were a time of increasing globalization when more people began to travel by air to far-flung destinations and when television began to show programmes made around the world, thereby opening up people's experience and views of the world. Global trade was increasing and mass-produced items such as refrigerators, cars and plastic became much-wanted goods. It became more common for people to own goods that were made in other countries (e.g. Europeans buying Ford cars made in the United States). It therefore became evident that there were increasing human and physical interlinkages between regions. It was also a period of modernity in which there was a societal commitment to order and rationality, and to science as the driving force for future developments and improvements in infrastructure and lifestyles. Physical geography needed to maintain its academic status and it could no longer do so within a society that now had a 'professional' science (see below). The Davisian cycles of erosion could not be verified from a scientific perspective and furthermore they did not *explain* observations. It was too difficult to measure such slow processes over such large spatial scales. Arthur Strahler, a geomorphologist particularly interested in rivers and landform change, proposed that a new dynamic basis for physical geography should be developed based on physical real-world measurements. It was also at this time that Hack (1960), a physical geographer, went into the Appalachians (coincidentally the very heart of the Davisian theory) and realized that landscapes were more delicately adjusted and that there was some form of equilibrium between rivers and landscapes. Box 1.1 describes these equilibrium approaches and their limitations.

It was also during this time that the work of G.K. Gilbert was revisited and his approach eventually embraced. This was largely due to the pioneering studies of the hydrologist Robert Horton and the development of his ideas by Strahler and his graduate students, who included Stanley Schumm, Marie Morisawa, Mark Melton and Richard Chorley. The 1950s are often referred to as the time of a quantitative revolution in geography due to the move away from description and towards measurement. Work began to concentrate on smaller spatial scales where processes could be measured during short-term studies.

1.2.3.2 Functional physical geography

However, although quantitative techniques were being employed these were not necessarily those that Gilbert had proposed. The measurements that were being performed in the 1950s and 1960s often did not allow us to evaluate or understand physical processes properly. They tended to be quantitative descriptions rather than the measurement of processes. For example, in 1953, Leopold and Maddock, physical geographers who studied rivers, published results of a survey of streams and rivers in the central and south-west United States. They found that stream width, depth and velocity increased in proportion to the discharge to the power of a given number (e.g. width is proportional to discharge to the power of 0.5; see Chapter 19). As the discharge increased downstream the equations suggested that channel width, mean depth and mean velocity should all increase. These equations could be used to make predictions about the discharge or **hydraulic geometry** of rivers across the world (see Chapter 19).

There are two problems with this approach. The first is that the relationships determined are purely statistical relationships (or functional relationships). In other words, they are just a result of the average value of the width, depth, velocity and discharge of all the rivers that were measured, but this does not explain *why* channel dimensions vary in such a way with discharge. These sorts of statistical relationship do not explain the physical processes. The second problem is that such functional approaches are often not applicable to areas other than the area for which they were determined. This is because

EQUILIBRIUM CONCEPTS IN PHYSICAL GEOGRAPHY

When Hack (1960) completed a field visit to the Appalachian Mountains he realized that rather than there being one long Davisian erosion process whereby rivers wore away mountains over time, there is in fact a more dynamic set of processes operating. He rejuvenated Gilbert's concept of 'dynamic equilibrium'. He suggested that every slope and every channel in an erosional system are adjusted to each other and that relief and form can be explained in spatial terms rather than historic ones. This work suggested that river profiles were never exactly concave. Instead, when sediment from a hillslope builds up in a river it has to steepen itself in order to move that sediment. Once removed, the river may become less steep in profile. In other words, the rivers and slopes would adjust to each other in an attempt to be in equilibrium.

Of course, the nature of equilibrium investigated depends on the timescale under investigation. Figure 1.4 shows forms of equilibrium over three timescales (Schumm and Lichty, 1965). Note that over short timescales it may be possible to identify a static equilibrium (no change over time) or a steady-state equilibrium (short-term fluctuations about a longer-term mean value) while over longer time periods the equilibrium might be dynamic (shorter-term fluctuations with a longer-term mean value that is changing).

However, the concept of equilibrium has always been somewhat confusing because different people have chosen to identify different types of equilibrium and because the precise meaning is time dependent. Indeed, equilibrium may be just as generalized and untestable as the Davisian cycle of erosion it was meant to replace. Often it depends on where and when you measure something as to whether it will show equilibrium. Figure 1.5 illustrates this very simply for two systems that in the long term are behaving differently. Because the measurements were done at the times shown in Figure 1.5, it was not possible to identify the nature of the long-term trend and in fact different trends have been determined from those that are actually occurring in the long term.

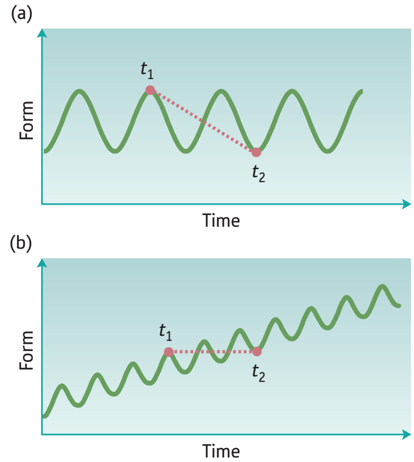

Figure 1.5 The timescale for human measurement makes it very difficult to identify long-term trends and the nature of equilibrium. Here the measurements are taken at two times (t_1 and t_2) for each case. However, because of the timing of the measurements we have incorrectly identified the nature of the long-term change in each case. In (a) we have established a downward trend where there is no long-term trend and in (b) we have identified no change while the long-term trend is upward.

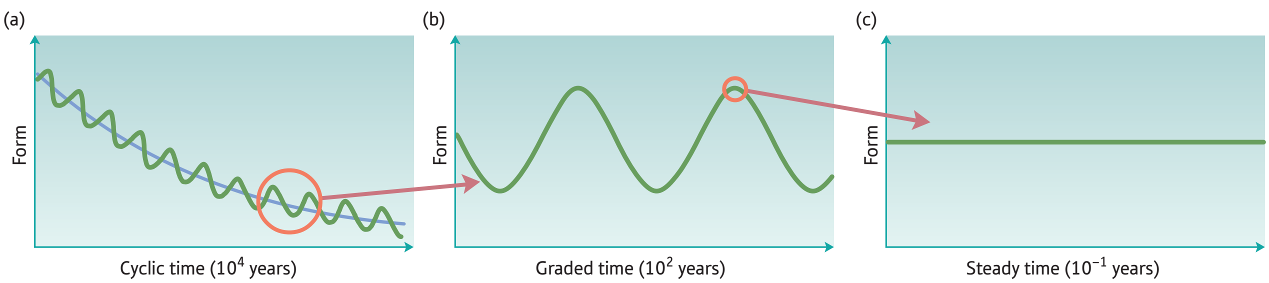

Figure 1.4 Equilibrium over three timescales: (a) dynamic equilibrium; (b) steady-state equilibrium; (c) static equilibrium.

BOX 1.1

local factors can influence the development of a landform (such as geology or tree roots on a river bank holding the bank together and preventing it from eroding) so that it does not conform to the statistical average. Indeed, sometimes it is the unusual cases that we are more interested in rather than the average. It was for these reasons that Yatsu (1992), a Japanese physical geographer with expertise in rock weathering, accused Strahler himself of 'crying wine and selling vinegar'. This means that he thought Strahler had advocated a new physical geography founded