# Unit One: The Earth System and its Components

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UNIT INFORMATION

Unit Overview

This unit introduces the idea of the earth system and its main components: the geosphere, atmosphere, hydrosphere and biosphere. The importance of adopting a systems perspective is outlined. However, in order to understand this approach, it is first necessary to consider some overviews and definitions of key terms and ideas: in particular, the terms ‘the environment’, ‘environmental science’ and ‘environmental management’. Understanding these terms is fundamental to understanding the science and management of the earth system and its components and processes. In addition, it is helpful to consider an overview of the current ‘environmental crisis’, which consists of a range of significant environmental issues together with a variety of other, related economic, social, political and technological issues. The seriousness of the current environmental crisis points to the importance of having a sufficient understanding of environmental science and management in order to respond to the many challenges it presents to policy-makers and other organisations and individuals.

Unit Aims

• To provide overviews and definitions of key terms and ideas, including ‘the environment’, ‘environmental science’, and ‘environmental management’.

• To present a brief overview of the current ‘environmental crisis’, which consists of a range of significant environmental issues and a variety of other, related issues.

• To explain the value of adopting a systems approach to the environment, identifying the main components of the earth system: the geosphere, atmosphere, hydrosphere and biosphere.

• To highlight the main flows occurring in the earth system, including the transfer of energy, and to explain the central role of biogeochemical cycles in the transfer of key materials.

Unit Learning Outcomes

By the end of this unit students should be able to:

• define the terms ‘environment’, ‘environmental science’ and ‘environmental management’

• state the main features of the current environmental crisis and the key environmental issues associated with that crisis

• define the earth system and describe its major components: geosphere, atmosphere, hydrosphere and biosphere

• list some of the main flows occurring in the earth system, especially the transfer of energy and the cycling of key materials in biogeochemical cycles
Unit Interdependencies

This unit provides introductory material that underpins Units 2–10, although it is of particular relevance to Units 2–6 in which the main components of the earth system are examined in greater detail. This unit also presents a brief overview that is of relevance to understanding the material presented in Units 9–10.
KEY READINGS

Section 1


Section 1 asks what do we mean by environmental management and outlines the current ‘environmental crises’. In this paper the authors identify ‘planetary boundaries’ (or thresholds) in nine key areas of environmental concern — beyond which they predict irreversible change in the earth system.

The boundaries identified cover processes operating at the global (or planetary) scale such as biogeochemical cycles and the major circulation systems of the planet; and processes occurring at the regional scale that when aggregated present a serious threat to earth system functioning. These will be considered in Units 2–6 and include biodiversity loss; pollution and land use change.

The aim of this reading is to emphasise the vital importance of understanding these processes for environmental management and also to demonstrate how these processes are interlinked.

You may wish to return to this reading again after you have completed Units 2–6.


This chapter provides an introduction to earth system science and explains some key concepts in systems analysis.

Section 2


This reading provides an account of the significance of global biogeochemical cycles, emphasising their reciprocal relationships and their disruption by human activities. The reading focuses on the major biogeochemical cycles of carbon, nitrogen and sulphur.
**Further Readings**


This chapter examines the importance of energy in environmental systems, including the main transfers, transformations and flows of energy in the earth system.


In this chapter, the major cycles of the earth system are outlined, including the carbon and nitrogen cycles.
REFERENCES


Available from: http://maps.grida.no/go/graphic/energy_consumption_economic_development_and_co2_emissions_selected_latin_america_countries [Accessed 8 August 2013]

1.0 THE ENVIRONMENT

Section Overview
This section presents overviews and definitions of some key terms and ideas: the environment, environmental science and environmental management. Understanding these terms is fundamental to understanding the science and management of the earth system and its components and flows. This section also presents a very brief overview of the current 'environmental crisis', which consists of a range of significant environmental issues and a variety of other related economic, social, political and technological issues.

Section Learning Outcomes
By the end of this section students should be able to:

• define the terms ‘environment’, ‘environmental science’ and ‘environmental management

• state the main features of the current environmental crisis and the key environmental issues associated with that crisis

1.1 What is ‘the environment’?

Define the term ‘environment’.

Many meanings
The term ‘environment’ is widely used and has a broad range of definitions, meanings and interpretations. What does the term ‘environment’ mean? In popular usage, for some people, the term ‘environment’ means, simply, ‘nature’: in other words, the natural landscape together with all of its non-human features, characteristics and processes. To those people, the environment is often closely related to notions of wilderness and of pristine landscapes that have not been influenced – or, at least, that have been imperceptibly influenced – by human activities. However, for other people, the term ‘environment’ includes human elements to some extent. Many people would regard agricultural and pastoral landscapes as being part of the environment, whilst others are yet more inclusive and regard all elements of the earth’s surface – including urban areas – as constituting the environment. Thus, in popular usage, the notion of the ‘environment’ is associated with diverse images and is bound up with various assumptions and beliefs that are often unspoken – yet may be strongly held. All of these usages, however, have a central underlying assumption: that the ‘environment’ exists in some kind of relation to humans. Hence the environment is, variously, the ‘backdrop’ to the unfolding narrative of human history, the habitats and resources that humans exploit, the ‘hinterland’ that surrounds human settlements, or the ‘wilderness’ that humans have not yet domesticated or dominated.
In its most literal sense, ‘environment’ simply means ‘surroundings’ (environs); hence the environment of an individual, object, element or system includes all of the other entities with which it is surrounded. However, in reality, individuals, objects, elements and systems rarely exist in isolation; instead, they tend to interact to varying extents with their surrounding entities. Therefore, it is not particularly helpful to conceptualise the ‘environment’ without including in that conceptualisation some notion of relationship. Individuals, objects, elements and systems influence – and are in turn influenced by – their surroundings. Indeed, the networks of relationships that exist between different entities may, in some cases, be extensive and highly complex. Thus the ‘environment’ may be regarded as a ‘space’ or a ‘field’ in which networks of relationships, interconnections and interactions between entities occur. To those who have studied the science of ecology, such a conceptualisation will be familiar, since ecologists are concerned with both the biotic (living) and abiotic (non-living) components of environmental systems – and especially with the interactions of those components. In fact, the term ‘environment’ is often used interchangeably with an ecological term ‘ecosystem’, which may be defined as a community of interacting organisms together with their physical surroundings. The notion of interrelationship is a central one in environmental science and management, since many environmental issues have occurred because one environmental system has been disturbed or degraded – either accidentally or deliberately – as a result of changes in another.

**A systems analysis approach**

By focusing on the interactions and interrelationships between different parts of the environment, we are using language that is characteristic of a systems analysis approach – or a systems framework – and applying it to the understanding of environmental science and management. Indeed, many environmental scientists now tend to think in terms of the whole ‘earth system’ and its components, subsystems and processes. In some ways, the term ‘earth system’ is a more useful one than ‘the environment’, not least because it highlights the fact that the natural world is a dynamic, complex entity with its own laws and processes, rather than being simply a passive space that is inhabited, exploited and given significance by humans. Moreover, increasingly, scientists have acknowledged that the study of environmental science and management should ideally be interdisciplinary in nature, so that insights from many academic disciplines and scientific specialisms are available to inform the study of environmental issues. This is particularly important when it comes to understanding complex global environmental issues, such as climate change, which affect all parts of the earth system and which require expertise beyond the scope of any single academic discipline. A further consideration is that the study of environmental science and management is, ultimately, focused on the planetary scale – since the earth system forms an integrated whole with many processes that operate globally. This is not to say that the study of environmental issues at other scales is unimportant; indeed, the management of localised environmental issues – such as the pollution of rivers – is critically important for human communities, livelihoods and well-being, as well as for the health and integrity of ecosystems. Nevertheless, the study and management of local and
regional environmental issues belongs – rightly – within a holistic, integrated, global context. And whilst the study of the earth system may be subdivided, for convenience, into categories such as ‘geosphere’, ‘atmosphere’, ‘hydrosphere’ and ‘biosphere’ – as well as into smaller categories – it is important to emphasise that such categories interact and overlap at all spatial and temporal scales.

1.2 What is environmental science?

A group of disciplines or a discipline in its own right

The term ‘science’ is derived from the Latin word for ‘knowledge’ (scientia); the term has come to mean the systematic collection of data relating to the observable universe and its constituent parts and processes. The pursuit of science involves the use of widely-accepted methods, techniques, principles and approaches including observation, identification, classification, description, analysis, experimentation, standardisation, hypothesis testing, falsification, verification and theory building. Yet ‘science’ is an umbrella term encompassing a wide range of branches of scientific knowledge, termed scientific disciplines and sub-disciplines, which may be categorised in various ways. The term ‘environmental science’ refers to a grouping of scientific disciplines that are all concerned with the physical, chemical and biological characteristics of the surroundings in which organisms live. Yet there is considerable overlap between these categories and between the disciplines themselves; hence the same phenomena (such as the earth’s oceans) may be studied within physics, chemistry, biology, ecology, oceanography, marine science, geology, geomorphology, seismology, sedimentology, climatology, meteorology, zoology, ichthyology, ornithology, planetary science, palaeoclimatology, palaeoecology and many other branches of science. Broadly, however, the environmental sciences contain two main sub-groupings: the life sciences (such as biology) and the earth sciences (such as geology). Furthermore, the environmental sciences include disciplines that are focused on present-day phenomena (such as meteorology) as well as on conditions that existed in the past (such as palaeoclimatology). Yet the term ‘environmental science’ also has a more precise meaning: it refers to a type of scientific discipline in its own right, one in which a broad range of insights from other branches of science are brought together (synthesised) to inform the understanding and management of contemporary environmental issues.

A focus on environmental change

By its nature, therefore, environmental science is interdisciplinary. It includes activities that are descriptive (such as studies of the ranges and distributions of individual species) as well as analytical (such as studies of the factors influencing those distributions, and of the ways in which they may alter in response to environmental change). Indeed, given that the earth system is dynamic – in other words, is constantly changing at all spatial and temporal scales – and because environmental changes can have profound consequences for human societies and economies, the work of environmental scientists frequently focuses on the investigation of process and change. In fact, the task of understanding environmental change is central to environmental science – yet it is a task that may present formidable challenges, for several reasons:
• scientific knowledge is cumulative, limited and partial; many environmental changes involve parts of the earth system that are not yet fully known or understood – as in the case of the extinction of species that have not yet been formally discovered or identified

• environmental changes may be cryptic: in other words, impossible (or extremely difficult) to detect, even using modern scientific techniques – as in the case of changes that occur in the genetic material of organisms but which are not immediately apparent in the structure or behaviour of those organisms

• environmental changes may occur over vast spatial scales, making it difficult to establish effective scientific monitoring programmes – as in the case of changes in the strength or direction of oceanic currents at the global scale

• conversely, environmental changes may occur over extremely small spatial scales, again making observation and monitoring difficult – as in the case of the contamination of soils and groundwater by nanoparticles

• environmental changes may occur over very long temporal scales, including the geological timescale, and they may be imperceptible over the average human lifespan – as in the case of changes in the amount of solar radiation received due to variations in the earth’s orbit

• conversely, environmental changes may be extremely rapid and their significance may not be appreciated until it is too late to conduct scientific monitoring and to establish baselines – as in the case of the collapse of an animal population following the outbreak of a virulent disease

• environmental changes may have occurred in the past when scientific monitoring techniques were not available, or were not used – as in the case of the historical rapid depletion of some whale species due to the operation of commercial fisheries

• environmental changes may involve complex environmental systems and subsystems, including myriad feedback mechanisms, and the causal relationships between the various components may not be known with sufficient certainty – as in the case of regional and local climate change due to radiative forcing

• environmental changes may have both natural and human (anthropogenic) causes, and it may be extremely difficult to disentangle the relative significance of each – as in the case of vegetation change in pastoral areas that have become drought-prone and desiccated

For reasons such as these, many concerns have been expressed about the accuracy and reliability of scientific knowledge and understanding of environmental change. Indeed, the subject of environmental change has become one of the most problematic and fiercely contested aspects of environmental science.

**Environmental science is intrinsically political**

It is important to emphasise a further point about environmental science: it is a subjective and value-laden activity. Despite the fact that most professional scientists attempt to use standardised, rigorous, replicable approaches and methods in their
work, the pursuit of science is never truly objective. Even if scientists themselves are motivated by the highest, noblest principles, their work is produced in diverse social, political and cultural contexts that are influenced by a variety of concerns besides the pursuit of impartial scientific knowledge and understanding. At a coarse level, decisions about which scientific studies receive funding tend to reflect contemporary economic, social, political and cultural priorities. A further issue is the fact that scientific disciplines are invariably highly specialised and technical, with the result that the communication between scientists and policy-makers often falls far short of being ideal. Consequently, articulate, eminent or well-connected representatives of the scientific community are sometimes able to wield undue influence in decision-making about the allocation of research funds. Added to this is the fact that governments, corporations, industry lobby groups and other campaigning organisations sometimes devote copious resources to their attempts to influence the conduct – and even the outcome – of scientific research studies. Therefore, the pursuit of science – including environmental science – is intrinsically political and, at times, highly controversial. The political nature of environmental science has been highlighted in many international negotiations about global environmental issues, including biodiversity loss and climate change. Some people would go further and argue that environmental science contains an ethical and moral, as well as a political, dimension; such a view is typically held by those who claim that environmental science should be used to support efforts, at all scales, to promote environmental stewardship, conservation and protection. Others disagree, arguing instead that (environmental) science should be free of subjective influences, as far as possible, and should not advocate a particular viewpoint; instead, it should focus purely on the collection and communication of robust, verifiable data.

Do you think it is acceptable for environmental scientists to advocate particular ethical, moral, political or personal viewpoints?

1.3 What is environmental management?

‘... but what exactly is environmental management? Is it a single field or discipline? Is it a process? Is it an agreed approach? Is it efforts to identify and pursue goals? Perhaps a philosophy? Or, is it environment and development problem solving?’

Source: Barrow (2005) p. viii

Define ‘environmental management’.

A diverse set of activities

Environmental management is not easy to define. As Barrow (2005) has acknowledged, it can refer to a goal or vision, to attempts to steer a process, to the application of a set of tools, to a philosophical exercise seeking to establish new perspectives towards the environment and human societies, and to much more besides. Environmental managers are a diverse group of people including academics, policy-makers, non-governmental organisation (NGO) workers, company employees, civil servants and a wide range of individuals or groups who make decisions about
the use of natural resources (such as fishers, farmers and pastoralists). Indeed, environmental management involves all people to some extent because all human activities ultimately have some sort of environmental impact. However, some individuals are more directly involved with resource use, and some special interest groups are particularly concerned with resource exploitation and with issues related to pollution. Environmental management therefore involves many stakeholders and requires a multidisciplinary perspective. It involves many spatial scales, ranging from the local to the global. It also involves many, diverse goals, including the desires to control the direction and pace of development, to optimise resource use, to minimise environmental degradation and to avoid environmental disaster. Environmental management may be practised by individuals and groups holding conflicting – and even directly opposing – views, as may be the case when environmental managers employed by large multinational corporations come into conflict with environmental managers representing voluntary organisations.

**A focus on decision-making**

In general, however, environmental management is concerned with the understanding of the structure and function of the earth system, as well as of the ways in which humans relate to their environment. Environmental management is therefore concerned with the description and monitoring of environmental changes, with predicting future changes and with attempts to maximise human benefit and to minimise environmental degradation due to human activities. Yet, characteristically, environmental management is about decision-making – and it is especially concerned with the process of decision-making in relation to the use of natural resources, the pollution of habitats and the modification of ecosystems. Fundamentally, then, environmental management is a political activity because those decisions – about resources, pollution and ecosystems – are never neutral or objective; on the contrary, they are value laden and they reflect the exercise of power by particular groups over others. Moreover, in general, it is naïve to conceive of environmental management as being about simply ‘the management of the environment’ in the sense of humans manipulating and controlling the components and processes of the earth system. Of course, humans do exert such influences on the earth system; but it is a fallacy to think that humans ‘manage’, for instance, populations of humpback whales. Instead, it is more accurate to suggest that humans may be able to make some progress towards managing human impacts on humpback whales. Ultimately, then, environmental management is more concerned with the management of human activities and their impacts than with the management of the natural environment *per se*.

**Influencing the course of development**

Nevertheless, some types of activity are common to environmental managers. Environmental managers attempt deliberately to steer the process of development in order to take advantage of opportunities; they attempt to ensure that critical environmental limits are not exceeded; they work to reduce and mitigate environmental issues; and they are concerned with increasing the adaptability and resilience of human societies in the face of environmental change, variability, unpredictability and hazards. From this point of view, environmental management may be defined as the system that anticipates and avoids, or solves, environmental and resource conservation issues. From another point of view, environmental
management may be defined as a process concerned with human-environment interactions which seeks to identify:

• what are environmentally desirable outcomes
• what are the physical, economic, social, cultural, political and technological constraints to achieving those outcomes
• what are the most feasible options for achieving those outcomes

Indeed, in many parts of the world (and arguably worldwide), environmental management is intimately linked with pressing issues of justice and even of survival. A further definition might suggest that environmental management is concerned with meeting and improving provision for human needs and demands on a sustainable basis with minimal damage to natural habitats and ecosystems. Thus the concept of environmental management is closely related to another important (and problematic) concept: that of sustainable development.

1.4 The environmental crisis

An unprecedented crisis

One of the most compelling reasons for studying environmental science and management is the fact that, in the view of many leading authorities, we are now experiencing an environmental crisis; indeed, many authors have claimed that the present environmental crisis is unprecedented in its magnitude, pace and severity (Park 2001). Awareness of this environmental crisis has grown since the 1970s, partly as a result of the prominence given to major so-called ‘environmental’ disasters such as the Sahelian droughts of the 1970s and 1980s and the nuclear accident at Chernobyl in 1986. A major assessment of the global environment published in 1999, the UNEP Global Environment Outlook 2000 report (UNEP 1999), drew attention to two critical, recurring themes:

• the fact that the global human ecosystem is threatened by grave imbalances in productivity and in the distribution of goods and services – as evidenced by the fact that a large proportion of the human population lives in poverty, and that a widening gap exists between those who benefit from economic and technological development and those who do not

• the fact that accelerating changes are occurring at the global scale, with rates of economic and social development outstripping progress in achieving internationally co-ordinated environmental stewardship – with the result that improvements in environmental protection due to new technologies are being ‘cancelled out’ by the magnitude and pace of human population growth and economic development

Consequently, a wide range of environmental problems has emerged; those problems include anthropogenic climate change (‘global warming’), the depletion of stratospheric ozone (the ‘ozone hole’), the acidification of surface waters (‘acid rain’), the destruction of tropical forests, the depletion and extinction of species, and the precipitous decline of biodiversity. Yet, while all of these problems have physical (environmental) manifestations, their causes – and their potential solutions – are invariably bound up with human attitudes, beliefs, values, needs, desires,
expectations, and behaviours. Thus the symptoms of the environmental crisis cannot be regarded purely as physical problems requiring solutions by environmental 'specialists'; instead, they are intrinsically human problems and they are intimately related to the question of what it means to be human.

Main features of the environmental crisis

At this point, a very brief overview of the environmental crisis may be helpful. It is important to emphasise that a wide range of views about the nature and severity of the current environmental crisis exists, and some of the issues are highly controversial. Nevertheless, there is broad agreement that the environmental crisis encompasses the following main issues.

- **Climate change**: anthropogenic climate change due to pollution of the atmosphere by greenhouse gases (and other contaminants) is now regarded as one of the major global environmental issues. It occurs largely as a result of the combustion of fossil fuels, emissions from agriculture and pastoralism, and land-use changes that accompany the destruction, clearance and burning of forests. Climate change already has observable ecological and social effects, and its projected impacts could potentially result in profound changes in global mean surface temperature, sea level, ocean circulation, precipitation patterns, climatic zones, species distributions and ecosystem function.

- **Stratospheric ozone depletion**: the depletion of stratospheric ozone due to the pollution of the atmosphere by halocarbons (such as chlorofluorocarbons, or CFCs) is another serious environmental issue. It is a significant concern because the lack of protective ozone at high altitudes results in increased levels of harmful solar ultraviolet (UV-B) radiation reaching the earth's surface, causing a range of health-related and ecological impacts.

- **Degraded air quality**: other forms of air pollution are also significant, particularly at regional and local scales, as they may seriously degrade air quality; worldwide, approximately one billion people inhabit areas – mainly industrial cities – where unhealthy levels of air pollution occur. Many air pollutants are responsible for the degradation of air quality, but some key pollutants include particulate matter (such as soot), tropospheric ozone, oxides of nitrogen, oxides of sulphur, lead and various aromatic compounds (such as benzene). Many air pollutants may cause or aggravate respiratory and cardiovascular illnesses; some are known carcinogens; and some can cause damage to vegetation and, in turn, produce a range of ecological effects.

- **Degraded water quality**: similarly, water quality can be seriously degraded by contamination with pollutants, giving rise to a range of health-related and ecological effects (such as the degradation of coral reefs). A major source of water pollution is the terrestrial run-off to inshore waters that occurs in many coastal locations; such run-off may contain significantly elevated levels of nitrogen and phosphorus from agricultural land and from human settlements. Many other human activities lead to water pollution, including mining and industrial processes, which may create toxic effluent. Oil spills, accumulation of plastics and the bioaccumulation of persistent organic chemicals are some of the other causes of serious degradation of the marine environment.
• **Scarcity of fresh water**: besides the pollution of freshwater sources, there are a variety of other reasons for the scarcity of fresh water for drinking in many parts of the world – many of which are related to poor water resource management practices. For instance, the over-abstraction of water from rivers results in water shortages and problems of salinisation downstream. Irrigation practices may also be responsible for the depletion of local water sources and the salinisation of irrigated land. Vast differences in water security exist at the global scale, reflecting both demand for fresh water and the scale of public and private investment in water supplies, treatment and distribution.

• **Land contamination**: land contamination occurs as a result of chemical or radioactive pollution, especially by long-lived (persistent) chemical species that enter the soil. Land contamination may cause profound ecological effects and it presents severe constraints to development, since contaminated land must typically be rehabilitated before it is safe to use for agriculture, construction or recreation.

• **Deforestation**: it has been estimated that around half of the world’s mature forests have been cleared by humans. Deforestation occurs for a variety of reasons, but the majority of deforestation now occurs when tropical forests are cleared for agriculture and pastoralism; other reasons include the destruction of trees for charcoal production and the selective logging of forests for timber. Whilst tropical forests cover only around 6% of the earth’s surface, they are an essential part of the global ecosystem and of the biosphere: they help to regulate climate; they protect soils from erosion; and they provide habitats for a vast number of plant and animal species. One estimate suggests that around 90% of the world’s species are found in tropical forests (Park 2001).

• **Soil erosion and degradation**: concerns about soil erosion, soil degradation and the problem of desertification have become acute. In part, these concerns are based on the historical experiences of dramatic soil erosion and transport in New World countries including the USA (during the ‘Dust Bowl’ of the 1930s) and Australia. Whilst analyses of the problems of soil erosion and degradation have become more sophisticated, recently, it is clear that these problems continue to have important consequences for agricultural and pastoral productivity as well as for the functioning of natural ecosystems.

• **Land use change and habitat loss**: these issues overlap with others, such as deforestation, but they are broader and include the clearance of forest for agriculture and pastoralism, the transformation of land during urban growth, the development of new infrastructure (such as roads), the drainage of wetlands, and the destruction and removal of coastal mangrove forests. The impact of land use change on forest and grassland environments is depicted in 1.4.1.

• **Biodiversity loss**: many plant and animal species are threatened with extinction, due to the spread of disease, the destruction and degradation of their habitats, and direct exploitation. In 1999, UNEP (1999) estimated that one-quarter of the world’s mammal species and around one-tenth of the world’s bird species faced a significant risk of total extinction. Threats to biodiversity are not confined to terrestrial ecosystems; serious concerns have been raised about the future of marine and coastal wildlife species as a result of the pollution, over-exploitation and acidification of ocean and seas.
1.4.1 Changes in ecosystems with different intensities of land use

Forest
- pristine forest
- selective logging
- secondary vegetation
- plantation
- land degradation

Grassland
- original species
- extensive use
- burning
- subsistence agriculture
- intensive agriculture

Abundance of original species

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Source: UNEP/GRID-Arendal (2009)
Other related issues

Some issues associated with the environmental crisis are not strictly ‘environmental’, but are closely related to environmental issues. They encompass a range of economic, social, political and technological issues.

- **Population growth**: the total human population has expanded since the introduction of agriculture, around 12,000 years ago, and its rate of growth has generally increased over time, largely as a result of increased food production and improved sanitation and health care. Achieving the first one billion of human population took most of human history, whilst the most recent increase of one billion was achieved in little more than a decade. However, recent declines in the rate of growth of population have occurred in many parts of the world, and in some countries populations are now declining. The total human population was around 5.9 billion in 1998; it currently far exceeds 6 billion people and is expected to have reached 9.4 billion people by 2050. The increasing human population inevitably places greater demands on the natural environment – for habitat, resources and waste assimilation – although the extent to which the human ‘population explosion’ is driving environmental degradation is a complex and controversial question. Significant differences exist in cultural attitudes to the issues of human population size and the rate of population growth.

- **Urbanisation**: the issue of urbanisation is indirectly related to that of population growth, since urbanisation is occurring in response to increasing population pressures in rural areas and to the increasing concentration of economic opportunities in cities – often in so-called ‘megacities’ (cities with populations exceeding 10 million people). Urbanisation is often associated with a range of social and environmental problems including overcrowding, congestion, pollution, public health issues, shortages of water for drinking, and inadequate sanitation. Urbanisation is also related to another issue: the decline of rural communities.

- **Poverty**: whilst poverty is complex and problematic to define, the persistence of poverty at all levels (from intra-household to global) represents an ongoing challenge, as acknowledged in most current development policies, initiatives and targets (such as the United Nations Millennium Development Goals (UNDP undated)). Vast differences in patterns of income, production and consumption are evident at all spatial scales, and those patterns are reflected in distinctive patterns of environmental impact (although in some cases environmental impacts are ‘exported’, as in the case of radioactive waste that is generated in one country before being transported to another for processing or disposal).

- **Food insecurity**: in general, the rate of increase in total food production has exceeded that of total population growth over recent decades, mainly due to improvements in agricultural practices and in water management techniques. However, the average values conceal enormous differences in the distribution and quality of food, and the lack of food security remains a profound challenge in many parts of the world. Debates about food production raise important environmental issues such as the use of genetically modified (GM) and genetically engineered (GE) seeds and produce.
• **Disease**: closely related to issues of poverty and food insecurity are problems of disease due to malnutrition, scarcity of water for drinking, poor sanitation, pollution, and inadequate shelter; those are often compounded by the spread of infectious diseases such as malaria, cholera, tuberculosis and HIV/AIDS. Large differences occur in the responses of human societies to diseases, reflecting vast inequalities in health care spending and in funding for pharmaceutical and medical research.

• **Peak oil and energy security**: peak oil refers to the time at which maximum crude oil extraction occurs, after which the economically viable reserves become depleted and the rate of oil extraction declines. Some estimates suggest that peak oil will occur – or has already occurred – early in the 21st century, with the implication that alternative energy sources will need to be developed in sufficient time to serve as a substitute for oil. Regardless of the accuracy of predictions about peak oil, the issues of climate change and conflict respectively, are now driving debates about ‘green’ (decarbonised or renewable) energy sources and energy security.

• **Conflict and displacement**: conflict between human societies continues to create severe environmental degradation in addition to human misery and a wide range of social impacts. For instance, the use of depleted uranium munitions causes significant land contamination, whilst the effects of the displacement of large numbers of people from zones of conflict can exert pressures on adjacent ecosystems. Displacement of people does not occur only in response to violence; globally, the effects of climate change are projected to result in the displacement of as many as 500 million environmental refugees.

**Natural disasters**

Whilst not necessarily part of the environmental crisis, human populations are also faced with ongoing threats due to the occurrence of natural disasters such as earthquakes, landslides, floods, tsunamis and wildfires. Yet whilst these hazards may be natural in origin, it is important to acknowledge that human vulnerability to natural disasters is generally increasing, not least because human populations and settlements are growing in many marginal and dangerous areas, such as floodplains. Hence unsustainable practices – such as the construction of settlements on floodplains, or the intensive cultivation of marginal hill slope lands – may greatly increase the impacts of natural disasters on human societies and economies.

**The causes of the environmental crisis**

The causes of the environmental crisis have been the subject of considerable debate. However, in general, its main causes are now acknowledged to be:

• **technological developments** over the course of human history – and particularly since the Industrial Revolution – which have allowed humans to exert a greater influence over natural resources and ecosystems
• rapidly increasing human population which has led to significant increases in human population density in many parts of the world

• dramatic increases in resource and energy consumption – particularly since the Industrial Revolution, and especially since around 1950 – which have accompanied economic growth and rising standards of living in some parts of the world as illustrated in 1.4.2.

1.4.2 Energy consumption, economic development and CO₂ emissions; selected Latin America countries

![Energy consumption, economic development and CO₂ emissions](source)

Source: UNEP/GRID-Arendal (2005b)
• **the emergence and development of the capitalist world economy** in which increasing flows of people, resources, products, energy and waste have occurred, together with increasing environmental impacts

• **utilitarian attitudes towards the environment** which have allowed the unrestricted exploitation of natural resources and ecosystems

• **short-term patterns of decision-making** exhibited by many governments, companies and individuals, which place greater emphasis on short-term profit maximisation (or value maximisation) than on environmental protection

For these reasons, amongst others, the environmental crisis presents an immense challenge to policy-makers and to many other organisations and individuals who must find creative responses to these issues – ideally, within an overall policy framework that promotes a sufficiently strong version of sustainable development.

amous, amongst others, the environmental crisis presents an immense challenge to policy-makers and to many other organisations and individuals who must find creative responses to these issues – ideally, within an overall policy framework that promotes a sufficiently strong version of sustainable development.

 ListItem the main issues that comprise the environmental crisis. As far as possible, categorise those issues according to (a) spatial scale; (b) time scale; and (c) the prospects for finding effective technological or policy solutions.
Section 1 Self Assessment Questions

Question 1

State some of the reasons why understanding environmental change is often a very challenging task.

Question 2

The 'ozone hole' is the result of the depletion of:

(a) carbon dioxide
(b) nitrous oxide
(c) tropospheric ozone
(d) stratospheric ozone

Question 3

Which of the following is an example of biodiversity loss?

(a) The disposal of radioactive waste at sea
(b) A reduction in the size of a whale population due to commercial whaling
(c) The extinction of an invertebrate species
(d) Reduced vegetation growth in conditions where nutrients are scarce
2.0 THE EARTH SYSTEM

Section Overview
This section explains the value of adopting a systems analysis approach to the environment, in which the entire global environment is considered to be the 'earth system'. In common with other systems, the earth system comprises components (which are often sub-systems) and flows. This section presents an overview of the main components and flows associated with the earth system. In particular, the earth system is often considered to have four main components: the geosphere, atmosphere, hydrosphere and biosphere (although there are various alternative ways of defining the earth system). A wide range of flows occurs in the earth system, although transfers of energy and materials represent the most important of these. Key materials are transported within the earth system via biogeochemical cycles.

Section Learning Outcomes
By the end of this section students should be able to:

- define the earth system and describe its major components: geosphere, atmosphere, hydrosphere and biosphere
- list some of the main flows occurring in the earth system, especially the transfer of energy and the cycling of key materials in biogeochemical cycles

2.1 Systems analysis in environmental science

Systems analysis
In recent decades, many valuable insights have been gained as a result of studying the environment using the methodology of systems analysis, which has been developed in order to investigate complexity in the real world (Smithson et al 2008 p. 9). Systems analysis emphasises the importance of understanding the structure of, and the relationships between and within, different parts of the environment. Indeed, the environment in its entirety may be regarded as a single system consisting of smaller, interconnected sub-systems. One particular way in which a systems analysis approach can be useful in understanding the environment is that it draws attention to the ways in which different parts of a system adjust to each other and to external factors. Systems analysis allows scientists to focus on the parts of the environment in which such adjustments occur. Indeed, as a result of the adoption of systems analysis by environmental scientists, the study of the environment has become a dynamic subject that is sharply focused on the knowledge and understanding of environmental adjustments and transformations (processes).

At the same time, by focusing also on entire systems, rather than simply on their component parts, systems analysis is a holistic – rather than a reductionist – approach to the study of the environment.

In order to understand such an approach to studying the environment, it is necessary first to consider some brief definitions of systems and some key terms associated with a systems analysis approach. What is a system? A system may be
defined as ‘a set of interconnected parts which function together as a complex whole’ (Smithson et al. 2008 p. 9). In other words, a system is a group of components that work together to perform a function. A commonly-cited example of a system is a computer; yet, many types of system occur and systems may be found at all spatial scales. Thus a single river may be regarded as an environmental system with components (such as tributaries, a main channel and a delta) that work together to perform a function (the transport of water, sediments and nutrients). Materials and energy move through systems via a series of flows, cycles and transformations; in the case of a river system, water, sediments, nutrients, living organisms, dissolved gases, pollutants and energy all pass through the system. Indeed, the components of a system may be regarded as stores, in which materials and energy come to rest for a certain period of time, and in which materials and energy may be modified or transformed. The term process is used to describe any transformation – physical, chemical or biological – that occurs in the environment; and the study of environmental systems often focuses on those processes, since it is often the case that changes in environmental systems are the most interesting and relevant aspects when it comes to understanding the environment. In fact, it may be more accurate to say that environmental science often focuses on process–response systems, in which case both the relevant processes and their environmental consequences are studied together in an integrated manner.

**System boundaries and scale**

For any system, it is important to define clear boundaries. System boundaries define the limits within which the components interact and thereby define the scale of the system and the ways in which different systems are interrelated. Environmental systems are physical systems with physical boundaries, and environmental conditions may change markedly across those boundaries. Some environmental system boundaries are relatively easy to define, such as the interface between the ocean and the atmosphere, or the watershed surrounding a river catchment. However, other environmental system boundaries are much less straightforward to define, such as the upper limit of the atmosphere (which is defined in a relatively arbitrary manner), or the limits of vegetation communities (which may undergo very gradual transitions). As well as defining the scale of a particular system, its boundaries also determine what type of system it is. Thus systems may be closed systems in which materials do not pass across the system boundary, or they may be open systems in which the relatively free exchange of materials occurs across the boundary. Open systems therefore have inputs and outputs; and the output of one system may form the input to another system (such systems are known as cascading systems). In relation to the earth system, the global water cycle is an example of a closed system because a finite amount of water is maintained within the environment and is transported internally but does not cross the system boundary (with the exception of any water that may have been delivered to the earth as a result of comet impacts). Most environmental systems are open systems, and are interconnected, with the result that changes in one component of one system may ultimately affect all of the other systems in some way.

**System scale** is another important consideration in defining and understanding environmental systems. Systems exist at all spatial scales, including the microscopic scale (such as a single bacterium) and the planetary scale. For instance, all of the living material on earth comprises a single system (the biosphere), but ecological
environments may also be defined at successively smaller scales (such as individual forests) – even at the level of single organisms (such as an individual tree). In some cases, the distinction between open and closed systems is purely a matter of scale; for instance, the global water cycle is typically regarded as a closed system, whilst the individual river catchments within it are obviously open systems. A further consideration is the fact that, because systems may be defined at different spatial scales, they may overlap. Systems may exist entirely within other systems (in a nested hierarchy), as in the case of an individual tree, which is part of a forest, which is part of the biosphere. For convenience, it is often helpful to define the subdivisions of a system as follows:

- **System** – which refers to the entire environmental system (such as a river drainage basin)
- **Sub-system** – which refers to major sub-divisions within the system (such as a floodplain)
- **System component (or system element)** – which refers to a part of the system or sub-system which has specific properties (such as the sediment load carried by a river)

For any environmental system, state one or more of its sub-systems and system components.

**Feedback loops and equilibrium**

Since most environmental systems are open and interconnected, the changes in any process–response system have effects on many – if not all – others. Such ‘knock-on’ effects are known as feedback loops. The term ‘feedback’ refers to the effect that occurs when the output of a system becomes an input to the same system (often for the purpose of control or self-correction (Smithson et al 2008 p. 12). Feedback loops may be positive or negative: positive feedback occurs when the effects of an original change are amplified or accelerated to produce a ‘snowballing’ effect; in contrast, negative feedback occurs when the effects of an initial change are ‘damped out’ by subsequent changes, with the result that the system reverts to its original condition. Many examples of each type of feedback loop are found in the environment. For instance, a positive feedback loop occurs when sea ice melts during the polar spring. As ocean and air temperatures increase, the sea ice begins to melt, with the result that the bright white, highly reflective surface of the ice is progressively replaced by open water, which is darker in colour and has a lower reflectivity (albedo). That lower reflectivity has the knock-on effect of increasing the amount of solar radiation that is absorbed at the surface, which in turn raises ocean and air temperatures further, leading to more rapid melting of the remaining sea ice. Hence this positive feedback loop amplifies and accelerates the original perturbation (the initial melting of sea ice).

In contrast, a negative feedback loop in the environment occurs as a result of the interaction between predators and their prey. In ideal conditions, one might expect the numbers of predators and prey animals to be approximately balanced, since the numbers of the former are usually dependent upon the numbers of the latter. If the number of prey animals temporarily increases (perhaps due to an unusually successful breeding season), then a short-term surplus of food becomes available for
the predators whose numbers may subsequently increase in response. But the greater number of predators will begin to have an impact upon the size of the prey population, which may reduce substantially, leaving the predators short of food. In ideal conditions, this negative feedback loop ensures that the number of prey animals remains relatively stable around a certain optimum number, since any change (increase or decrease) in prey numbers leads to a response in predator numbers which has the knock-on effect of damping out the original perturbation (the initial rise or fall in the number of prey animals). The existence of feedback loops raises an important and interesting question in environmental science: to what extent are environmental conditions maintained in a state of equilibrium? In other words, do environmental systems tend to exist in stable states (which may be disrupted by human activity, but to which environmental processes will tend to restore those systems)? Or, alternatively, are environmental systems inherently unstable (chaotic), with no particular equilibrium state to which they tend to revert? Or, in yet another possibility, are environmental systems semi-chaotic – displaying stability under certain conditions, but becoming unstable if certain thresholds are exceeded? These are very complex and difficult questions, and they present significant challenges to environmental scientists.

2.2 Defining the earth system

The main components of the earth system

The earth system is itself an integrated system, but it can be subdivided into four main components, sub-systems or spheres: the geosphere, atmosphere, hydrosphere and biosphere. These components are also systems in their own right and they are tightly interconnected. The four main components of the earth system may be described briefly in the following way.

- **The geosphere** – this is the part of the planet composed of rock and minerals; it includes the solid crust, the molten mantle and the liquid and solid parts of the earth’s core. In many places, the geosphere develops a layer of soil in which nutrients become available to living organisms, and which thus provides an important ecological habitat and the basis of many forms of life. The surface of the geosphere is subject to processes of erosion, weathering and transport, as well as to tectonic forces and volcanic activity, which result in the formation of landforms such as mountains, hills and plateaux.

- **The atmosphere** – this is the gaseous layer surrounding the earth and held to its surface by gravity. The atmosphere receives energy from solar radiation which warms the earth’s surface and is re-emitted and conducted to the atmosphere. The atmosphere also absorbs water from the earth’s surface via the process of evaporation; it then acts to redistribute heat and moisture across the earth’s surface. In addition, the atmosphere contains substances that are essential for life, including carbon, nitrogen, oxygen and hydrogen.
2.2.1 The earth system as a set of four overlapping, interacting spheres

See the e-study guide for an animated version of this diagram.

Source: unit author
• **The hydrosphere** – this consists of those parts of the earth system composed of water in its liquid, gaseous (vapour) and solid (ice) phases. The hydrosphere includes: the earth’s oceans and seas; its ice sheets, sea ice and glaciers; its lakes, rivers and streams; its atmospheric moisture and ice crystals; and its areas of permafrost. The hydrosphere includes both saltwater and freshwater systems, and it also includes the moisture found in the soil (soil water) and within rocks (groundwater). Water is essential for the existence and maintenance of life on earth. In some classifications, the hydrosphere is subdivided into the fluid water systems and the **cryosphere** (the ice systems).

• **The biosphere** – this contains all living organisms and it is intimately related to the other three spheres: most living organisms require gases from the atmosphere, water from the hydrosphere and nutrients and minerals from the geosphere. Living organisms also require a medium for life, and are adapted to inhabit one or more of the other three spheres. However, much of the biosphere is contained within a shallow surface layer encompassing the lower part of the atmosphere, the surface of the geosphere and approximately the upper 100 metres of the ocean. Humans are part of the biosphere, although they are increasingly responsible for the creation of systems that may be largely artificial (such as cities).

The main components of the earth system are interconnected by **flows** (also known as **pathways** or **fluxes**) of energy and materials. The most important flows in the earth system are those concerned with the transfer of energy and the cycling of key materials in biogeochemical cycles.

**Energy flows**

The earth is a vast, complex system powered by two sources of energy: an internal source (the decay of radioactive elements in the geosphere, which generates geothermal heat) and an external source (the solar radiation received from the Sun); the vast majority of the energy in the earth system comes from the Sun. Whilst some variations in these two sources occur, their energy supplies are relatively constant and they power all of the planet’s environmental systems. Indeed, energy both drives and flows through environmental systems, and energy pathways may be highly complex and difficult to identify. For instance, energy may take the form of latent heat which is absorbed or released when substances change state (for example, between the liquid and gaseous phases). An example of energy flow and transformation through an ecosystem is illustrated in 2.2.2.

Energy is transferred within and between environmental systems in three main ways:

• **radiation** – this is the process by which energy is transmitted through space, typically in the form of electromagnetic waves

• **convection** – this is the physical movement of fluids (such as water or air) that contain energy in the form of heat; convection does not occur in solids

• **conduction** – this is the transfer of energy in the form of heat through the substance of a medium (from molecule to molecule)
2.2.2 Simplified depiction of energy flows and transformations in terrestrial ecosystems

As well as being transferred within environmental systems, energy may also be transformed from one form to another; for instance, a rock fall involves the conversion of potential energy (due to gravity) to kinetic energy (due to movement) and to thermal energy, or heat (due to friction). The transfer and transformation of energy are associated with the performance of work; hence the sun performs work in heating the earth by its radiation, and a glacier performs work in moving sediment down-slope using the kinetic energy of its ice, water and rock. When work is carried out within the earth system, energy is transferred from one body to another, and it may also be converted from one form to another in the process. Throughout environmental systems, as energy is transformed from one form to another in performing work, heat is released; that heat is subsequently exported from the system, usually into the atmosphere and then into space. Yet the total energy content of the earth system remains the same (it is conserved), for energy cannot be created or destroyed. It follows that the earth system is only able to continue to function because it is constantly replenished with a sufficient supply of energy (mainly from the sun).
The dominant flows of energy at the global scale occur as a result of the large discrepancies that occur between the amounts of solar radiation received (and re-emitted) at different points on the earth’s surface. Such discrepancies are most clearly apparent in the wide variations in surface temperature that exist between the equator and the poles. Those temperature variations drive the global energy circulation which acts to redistribute heat from the warm to the cold parts of the earth’s surface. An overall poleward transfer of energy occurs by means of a variety of processes: the transfer of heat by winds and warm air masses; the transfer of latent heat associated with water vapour; the movement of heat in ocean currents; and the returning counter-flows of cooler air and water. The three main processes of energy transfer at the global scale may be summarised as:

- the horizontal transfer of sensible heat by the movement of warm air masses
- the transfer of latent heat in the form of atmospheric moisture
- the horizontal convection of sensible heat by ocean currents

It is important to acknowledge that pronounced latitudinal variations occur in these three processes. Overall, however, these processes of energy transfer maintain a state of equilibrium in the earth system: they remove energy from areas of surplus (in lower latitudes) and transfer it to areas of deficit (in higher latitudes).

**Biogeochemical cycles**

The earth system contains several ‘great cycles’ in which key materials are transported through the environment. In general, cycles occur in closed systems; at the global scale, many systems may be assumed to be closed because the earth receives negligible quantities of minerals from space (as a result of meteorite impacts) and because only limited quantities of materials can escape the earth’s atmosphere. The key materials that cycle through the major biogeochemical cycles are carbon, oxygen, hydrogen, nitrogen, phosphorus and sulphur – all of which are essential for life. The biogeochemical cycles operate at the global scale and involve all of the main components of the earth system; thus materials are transferred continually between the geosphere, atmosphere, hydrosphere and biosphere. However, since the biogeochemical cycles involve elements that are essential for life, organisms play a vital part in those cycles. Typically then, the biogeochemical cycles involve an inorganic component (the abiotic part of the cycle, including sedimentary and atmospheric phases) and an organic component (comprising plants and animals, both living and dead). Like other environmental systems, biogeochemical cycles involve the flow of substances between stores (also known as reservoirs) in the geosphere, atmosphere, hydrosphere and biosphere. Water plays a vital role in mediating many of the flows between stores.

Three of the key biogeochemical cycles are the nitrogen, carbon and sulphur cycles, whose main features are described here.

- **The nitrogen cycle** – the nitrogen cycle is a relatively fast and highly complex cycle. Most of the atmosphere consists of gaseous nitrogen which is ‘fixed’ (in other words, made available for use by plants) biologically in soils. Soil bacteria convert nitrogen to ammonia; this, together with inorganic nitrate, is absorbed by plant roots and converted to organic compounds (such as proteins) in plant tissues. These compounds are eaten by herbivores; in turn, nitrogenous
compounds are passed to carnivores, and they are ultimately returned to the soil in the form of nitrogenous waste products (such as urine and faeces) and as a result of the death and decomposition of organisms. Bacteria then convert the organic nitrogen compounds into ammonia and ammonium compounds, which are then converted by bacteria into nitrites and then nitrates, which are then available for re-uptake by plants. Some of the nitrogenous compounds that are not absorbed by plants are leached from the soil into groundwater, surface water and ultimately into seas and oceans. Of that nitrogenous material, some is used by aquatic plants, some accumulates as organic sediment, and some evaporates into the atmosphere. The cycle is completed by denitrifying bacteria which eventually convert nitrates and nitrites to ammonia, nitrogen and nitrogen oxides.

- **The carbon cycle** – carbon is stored in the atmosphere in the form of carbon dioxide, which is absorbed by plants and converted to carbohydrates by the process of photosynthesis.

  The cycle then follows food chains, with carbohydrates being consumed by herbivores and then carnivores, being metabolised during the process of respiration. Carbon dioxide is returned to the atmosphere as animals exhale and when organic waste and dead organisms decay. Vegetation and animals are thus important stores of carbon, although that carbon may be rapidly returned to the atmosphere if vegetation is burned. Soils are also important reservoirs for carbon. Atmospheric carbon dioxide is soluble in water, in which it forms carbonic acid, which forms bicarbonate ions and carbonate ions, which in turn form salts (such as the insoluble calcium carbonate, which accumulates in marine sediments, marine organisms and carbonate rocks, such as limestone). Carbon is typically stored in these forms until it is released to the atmosphere by chemical weathering. A diagrammatic representation of the carbon cycle is presented in 2.2.3.

- **The sulphur cycle** – sulphur is released into the atmosphere during volcanic eruptions (in the forms of sulphurous gas, dust and particles) and as a result of the weathering of rocks. The oceans also play an important role in the sulphur cycle, as marine phytoplankton produce dimethyl sulphide, some of which enters the atmosphere and is converted to sulphur dioxide and sulphate aerosols. These compounds are ultimately converted to sulphuric acid and are deposited on the earth’s surface in precipitation. In terrestrial ecosystems, bacteria break down sulphurous compounds and release the sulphur to the atmosphere again, mainly in the form of hydrogen sulphide.

Of course, biogeochemical cycles have been substantially modified by human activities – a fact that has enormous implications for the understanding and management of environmental issues.
2.2.3 Carbon cycle

Source: UNEP/GRID-Arendal (2005a)
Section 2 Self Assessment Questions

Question 4

True or false?

In an environmental system, the damping out of the effects of an initial change by subsequent changes is known as positive feedback.

Question 5

Match the following definitions to the table below:

(i) is mostly contained within a shallow surface layer
(ii) consists of the earth’s crust, mantle and core
(iii) contains both fluid water and ice systems
(iv) is the gaseous layer in which heat and moisture are redistributed

<table>
<thead>
<tr>
<th>(a) the atmosphere</th>
<th></th>
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<tbody>
<tr>
<td>(b) the biosphere</td>
<td></td>
</tr>
<tr>
<td>(c) the hydrosphere</td>
<td></td>
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<tr>
<td>(d) the geosphere</td>
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Question 6

Which of the following is NOT a major process of energy transfer at the global scale?

(a) The transfer of latent heat in the form of stratospheric ozone.
(b) The transfer of latent heat in the form of atmospheric moisture.
(c) The horizontal convection of sensible heat by ocean currents.
(d) The horizontal transfer of sensible heat by warm air masses.
UNIT SUMMARY

This unit has presented some overviews and definitions of key terms and ideas in relation to the environment, environmental science and environmental management. Understanding these terms is fundamental to understanding the science and management of the earth system and its components and flows. This unit has also presented a brief overview of the current ‘environmental crisis’, which consists of a range of significant environmental issues and a variety of other, related economic, social, political and technological issues. Whilst, historically, scientists adopted a largely descriptive approach to the natural world, over the last several decades a systems analysis approach has been used to study the environment. From this perspective, the entire global environment is considered to be the ‘earth system’ and it comprises components and flows. This unit has presented an overview of the main components and flows of the earth system. In particular, the earth system is often considered to have four main components: the geosphere, atmosphere, hydrosphere and biosphere (although some authors also regard the cryosphere as a distinct component). A wide range of flows occurs in the earth system, although transfers of energy and materials represent the most important of these. Key materials are transported within the earth system via biogeochemical cycles, including the great cycles of nitrogen, carbon and sulphur upon which all living organisms depend.
UNIT SELF ASSESSMENT QUESTIONS

Question 1

In relation to environmental systems, state briefly what you understand by the following terms:

(a) stable states
(b) unstable or chaotic states
(c) semi-chaotic states

Question 2

The three main ways in which energy is transferred within and between environmental systems are:

(a) evaporation, condensation and transport
(b) condensation, latent heat and radiation
(c) condensation, conduction and convection
(d) conduction, convection and radiation

Question 3

Which of the following statements is NOT true?

(a) The nitrogen cycle is a rapid and complex biogeochemical cycle.
(b) Carbon is released to the atmosphere in the process of respiration.
(c) The production of dimethyl sulphide is part of the sulphur cycle.
(d) The major biogeochemical cycles can operate in the absence of water.
**Key Terms and Concepts**

**abiotic** non-living

**albedo** the reflectivity of a surface

**anthropogenic** caused by human activity

**atmosphere** the gaseous layer surrounding the earth

**biosphere** all living organisms

**biotic** living

**cascading system** a system in which the output of one sub-system forms the input to another sub-system

**closed system** a system in which materials do not pass across the system boundary

**conduction** the transfer of energy in the form of heat through the substance of a medium (from molecule to molecule)

**convection** the physical movement of fluids (such as water or air) containing energy in the form of heat

**ecosystem** a community of interacting organisms together with their physical surroundings

**food chain** the transfer of energy and materials from plants to herbivores to carnivores

**geosphere** the part of the planet composed of rock and minerals

**habitat** a particular environment in which a species lives

**hydrosphere** those parts of the earth system composed of water in its liquid, gaseous (vapour) and solid (ice) phases

**latent heat** heat that is used not to raise the temperature of a body but to change its state

**nested hierarchy** a system in which smaller sub-systems are entirely contained within larger sub-systems

**open system** a system in which the relatively free exchange of materials occurs across the system boundary

**peak oil** the time at which maximum crude oil extraction occurs, after which the economically viable reserves become depleted and the rate of oil extraction declines

**process** any physical, chemical or biological transformation that occurs in the environment

**radiation** the process by which energy is transmitted through space, usually in the form of electromagnetic waves

**sensible heat** heat that increases the temperature of a body and is exchanged down a temperature gradient
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>stratospheric</td>
<td>occurring in the stratosphere, around 12–45 kilometres above the earth’s surface</td>
</tr>
<tr>
<td>tropospheric</td>
<td>occurring in the troposphere, around 0–12 kilometres above the earth’s surface</td>
</tr>
<tr>
<td>urbanisation</td>
<td>the process by which the proportion of the human population that inhabits urban areas is increasing</td>
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