# CHAPTER 1: INTRODUCTION TO PHYSICAL GEOGRAPHY

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**Earth and physical geography**. Physical geography is a science based discipline that studies the natural phenomena associated with the Earth. It differs from earth science by having a strong spatial perspective. *(Source: NASA)*

## STUDENT LEARNING OUTCOMES

### *After reading this chapter you should be able to:*

- Define physical geography and its corresponding sub-disciplines.
- Describe the historical development of physical geography.
- Summarize current trends in the discipline of physical geography.
- Outline physical geography's relationship with geography and other fields of knowledge.
- Discuss the relationship of physical geography to the study of our planet's atmosphere, biosphere, hydrosphere, and lithosphere.
- Define and explain how the science of physical geography works.
- Explain how systems theory is used to enhance scientific understanding.

# INTRODUCTION

The main objective of this textbook is to introduce students to the exciting field of knowledge known as physical geography. **Physical geography** is a discipline that is part of a much larger area of study called geography. Most individuals define geography as a field of study that deals with maps. This definition is far from being correct. A more precise definition of **geography** is the study of natural and human phenomena relative to a spatial dimension.

Geography has a history that stretches over many centuries. Over this time period, the study of geography has evolved and developed into an important form of scholarship. Examining the historical evolution of geography as a discipline provides some important insights concerning its character and method. These insights are also helpful in gaining a better understanding of the nature of physical geography.

## HISTORY OF GEOGRAPHY AND PHYSICAL GEOGRAPHY

Physical geography has a history that spans several thousand years. Further, this history is often intertwined with developments in geography's other major field of study, human geography. Some of the first applications of knowledge involving physical geography occurred more than four thousand years ago. The main purpose of these early investigations was to map the natural landscape and human settlements observed as explorers traveled to new explored lands. At this time, Chinese, Egyptian, and Phoenician civilizations were beginning to explore the spaces and places within and around their homelands. The earliest evidence of such explorations comes from the archaeological discovery of a Babylonian clay tablet map that dates back to 2300 BC.

### Early Greeks and Romans

The early Greeks were the first civilization to practice a form of physical geography that was more than just drawing the location of natural and human-made features on maps. The ancient Greeks were also interested in the shape, size, and geometry of the Earth. Aristotle (circa 384 - 322 BC) hypothesized and logically demonstrated that the Earth had a spherical shape. Evidence for this idea came from his observations of lunar eclipses. Lunar eclipses occur when the Earth casts its circular shadow on to the moon's surface.

The first individual to accurately calculate the circumference of the Earth was the Greek geographer Eratosthenes (circa 276 - 194 BC). Eratosthenes calculated the equatorial circumference to be 40,233 km (25,000 mi) using simple geometric relationships. This calculation was unusually accurate considering the primitive technology used. Measurements using advanced satellite technology have computed the Earth's circumference to be 40,072 km (24,900 mi).

Most of the Greek accomplishments in physical geography were passed on to the Romans. Military commanders and administrators used this information to help direct the expansion of Roman Empire. The Romans also made several important contributions to human and physical geography. Strabo (circa 64 BC - AD 20) wrote an extensive 17-volume series called *Geographia*. Strabo traveled widely across the Roman Empire, and *Geographia* recorded what he had observed and experienced from a mainly geographical perspective.

During the second century AD, Ptolemy (circa AD 100 - 178) made a number of important contributions. Ptolemy's publication *Geographike hyphegesis* or *Guide to Geography* compiled and summarized much of the Greek and Roman geographic information accumulated at that time. Some of his other important contributions include the creation of three different methods for projecting the Earth's surface on a map, the calculation of coordinate locations for some eight thousand places on the Earth, and the development of the concepts of latitude and longitude (**Figure 1.1**).

### Middle Ages to 1800

Little academic progress in geography occurred after the Roman period. For the most part, the Middle Ages (5th to 13th centuries AD) were a time of intellectual stagnation in most of Europe. The Vikings of Scandinavia were the only group of people carrying out active exploration of new lands. In the Middle East, Arab academics began translating the works of Greek and Roman scholars starting in the 8th century and began exploring the physical and human geography of southwestern Asia and Africa. Some of the important Arab geographers include Al-Idrisi, Ibn Battuta, and Ibn Khaldun. Al-Idrisi is best known for his skill at making maps and for his work of descriptive geography *Kitab nuzhat al-mushtaq fi ikhtiraq al-afaq* or *The Pleasure Excursion of One Who Is Eager to Traverse the Regions of the World*. Ibn Battutah and Ibn Khaldun are well known for writing about their extensive travels in North Africa and the Middle East. In China, academics


**FIGURE 1.1** This early map of the world was constructed using map-making techniques developed by Ptolemy. Note that the map is organized with crisscrossing lines of latitude and longitude. *(Source: Wikipedia)*

were using sophisticated geometric techniques to produce high quality maps of their homeland.

During the Renaissance (AD 1400 to 1600) numerous journeys of exploration were commissioned by a variety of nation states in Europe. Most of these expeditions were financed because of the potential commercial returns from resource exploitation. These voyages also offered an opportunity for scientific investigation and discovery. Consequently, these explorations added many significant contributions to understanding the physical geography of the Earth. Influential explorers of this period include Christopher Columbus, Vasco da Gama, Ferdinand Magellan, Jacques Cartier, Sir Martin Frobisher, Sir Francis Drake, John and Sebastian Cabot, and John Davis.

The Renaissance was also a time of many technological inventions. Some of these discoveries were made to improve navigation across the Earth's surface and to better the production of maps. In 1492, Martin Behaim created a spherical globe depicting the Earth in its true three-dimensional form (**Figure 1.2**). Behaim's invention was a significant advance over two-dimensional maps because it created a more realistic depiction of the Earth's actual shape and surface configuration.

In the 17th century, Bernhardus Varenius (1622-1650) published an important geographic reference titled *Geographia generalis* (*General Geography*: 1650). In this volume, Varenius used direct observations and primary measurements to present some new ideas concerning geographic knowledge. His work continued to be a standard geographic reference for about 100 years. Varenius also suggested that the discipline of geography could be subdivided into three distinct fields of knowledge. The first field examines the shape, dimensions, and motions of the Earth. The second field deals with tides, the relationship between day length with latitude and time, climatic variations, and other variables that are influenced

Martin Behaim (AD 1459-1507) was geographer and navigator to the King of Portugal. *(Source: Wikipedia)*

by the cyclical movements of the Earth and moon. Together these two fields form the early beginning of what is now collectively called physical geography. The last field of geography examined distinct regions on the Earth studying the political, economic, cultural, and social behavior of people. Today, this area of geographic knowledge is known as **human geography**.

During the 18th century, the German philosopher Immanuel Kant (1724-1804) proposed that human knowledge could be organized in three different ways. One way of organizing knowledge was to classify its facts according to the type of objects studied. Accordingly, zoology studies animals, botany examines plants, and geology involves the investigation of rocks. The second way one can study things is according to a temporal dimension. This field of knowledge is of course called history. The last method of organizing knowledge involves understanding facts relative to spatial relationships. This observation elevated the importance of geography as a major form of scholarship. Kant also divided geography into a number of fields of knowledge. He recognized the following six branches: theological, mathematical, moral, political, commercial, and physical geography.

## 1800 to 1950

During the late 1700s and early 1800s, academics began doubting the belief that the Earth's landscapes were the result of relatively recent catastrophic events. The prevailing view at that time was that the Earth was created through supernatural means and had been affected by a series of catastrophic events such as the biblical Flood. The theory of uniformitarianism suggested that the landscape developed over long periods of time through a variety of slow natural processes. The ideas behind uniformitarianism originated with the academic work of Scottish geologist James Hutton. In 1785, Hutton presented at several meetings of the Royal Society of Edinburgh that the Earth had a long past and that this history could be fully understood in terms of processes currently observed. For example, he suggested that deep soil profiles were formed by the weathering of bedrock over tens of thousands of years.

Hutton's ideas did not gain significant support from the scientific community until the work of Charles Lyell. In the publication Principles of Geology (1830-1833), Lyell presented a variety of geologic evidence from England, France, Italy, and Spain to prove Hutton's ideas correct. The theory of uniformitarianism was also important in shaping the development of ideas in disciplines outside of the geosciences. The work of Charles Darwin and Alfred Wallace on the origin of the Earth's species extended the ideas of uniformitarianism into the biological sciences. The theory of evolution is based on the principle that the diversity seen in the Earth's species can be explained by the uniform modification of genetic traits over long periods of time.

The 19th century saw the emergence of a number of societies interested in geographic issues in Europe and the United States. The first of these societies was established in Paris in 1821. The founding of geographical societies in Germany in 1828 and Britain in 1830 quickly followed. The American Geographical Society was formed in 1852, and by 1866 there were eighteen established geographical societies worldwide. During the 19th century we also see the establishment of many University Chairs in geography, many of which were in areas of study that fall squarely in the realm of physical geography.

At University of Neuchâtel in Switzerland, Louis Agassiz began studying glaciers and their effect on the Earth's landscape in 1836. From field observations of alpine glaciers in the Alps, Agassiz developed an excellent understanding of how glaciers modify the landscape. Four years later, Agassiz published the theory that a great Ice

Age had once dominated the planet. This theory was based on observations in the highlands of Scotland where he saw the remnant effects of glaciers on the landscape. In 1846, Agassiz came to the United States and found evidence that past glaciation also influenced the landscape of North American continent.

In Germany, Alexander von Humboldt and Carl Ritter made substantial contributions to physical geography. Humboldt's publication *Kosmos: A General Survey of the Physical Phenomena of the Universe* (1844) examines the geology and physical geography of the Earth (**Figure 1.3**). This work is considered by many academics to be a milestone contribution to scholarship in physical geography. The work of Carl Ritter investigated the dynamic relationships that exist between humans and their natural environment. From this investigation, Ritter suggested that regional variations in nature of the environment produced different outcomes in this relationship.

In 1847, George Perkins Marsh gave an address to the Agricultural Society of Rutland County, Vermont. The theme of this speech was that human activity was having a destructive impact on the landscape, mainly through deforestation and land conversion. This speech also became the foundation for his book *Man and Nature* or *Physical Geography as Modified by Human Action*, first published in 1864. In this publication, Marsh more fully explained the environmental consequences of the unceasing development of the American frontier. Marsh's work marks the beginning of an important field of research in physical geography – the study of how human activities degrade the natural environment of the Earth.

Intellectual expansion in the late 19th century set the stage for the fracturing of physical geography into a number of major subfields in the early 20th century. In Russia, V.V. Dokuchaev and his associates established pedology and introduced the idea that spatial variations in soil type could be explained in relation to parent material, climate, and topographic factors. Wladimir Köppen suggested that one could classify the Earth's local climates based on regional variations in temperature and precipitation. Research at Meteorological Institute at Bergen, Norway laid the groundwork for the development of meteorology and climatology as disciplines. The work of Frederic Clements and Henry Cowles lead to elaborate theories of plant succession common to biogeography and ecology.

Late 19th century contributions from W.M. Davis and G.K, Gilbert helped to make geomorphology the dominant field of specialization for physical geographers over the next 100 years. Davisian cycles of erosion and his subsequent classification scheme of landscape development were in vogue with geomorphologists for about half a century. This success was mainly due to the fact that this theory could be applied to a variety of landscapes and required only simple descriptive data. Gilbert's alternative approach tried to use quantitative methods to determine the exact processes responsible for landscape evolution. This process-oriented approach to geomorphology did not

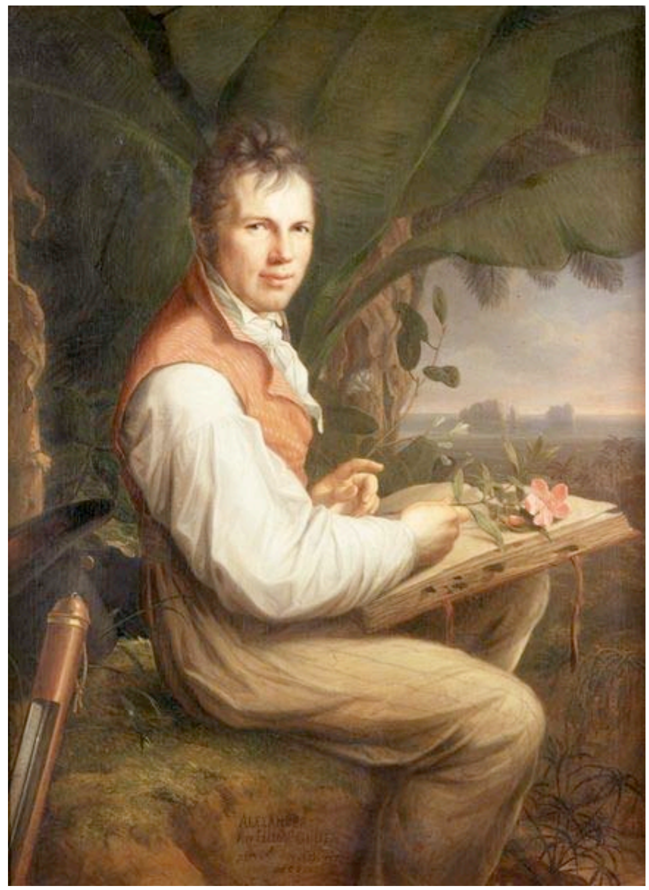

**FIGURE 1.3** German naturalist and explorer Alexander von Humboldt (AD 1769 to 1859) made some of the first significant academic contributions to physical geography and biogeography. Von Humboldt is best known for his exploration of Mexico, Central America, and South America. During his travels, he collected thousands of plant specimens, rock samples, made many drawings of exotic animals, and constructed maps of the newly discovered landscape. He also correctly theorized that cold ocean currents and prevailing winds off the coast of South America were responsible for the development of the desert found on the Peruvian coastal plain. Some of his other contributions include the idea that climate and altitude influence the distribution of plants in a similar way, the concept of continentality, and the discovery of permafrost in the Russian north. *(Source: Wikipedia)*

become popular until the 1950s because of its need for advanced numerical techniques.

The number of researchers in the various fields of physical geography increased considerably during the first three decades of the 20th century. These researchers helped develop physical geography mainly through basic data collection, the creation of classification schemes to organize the data collected, and by postulating theories of operating processes through inductive logic. Data collection included activities such as determining the elevation of land surfaces, the classification and description of landforms, the measurement of the volume of flow of rivers, measurement of various phenomena associated with weather and climate, and the classification of climate, soils, organisms, biological communities, and ecosystems.

During the 1930s and 1940s physical geography slid into steady decline in importance in the academic world. At the heart of this decline was the fact that the discipline was having problems attracting new students, with fresh ideas. Descriptive based approaches to physical geography that were very popular in the late 19th and early 20th century were now tired and uninteresting. Physical geography needed a radical shift in philosophy to attract new scholars.

## 20th Century – Second Half

Starting in about 1950, research in physical geography experienced a fundamental shift in philosophy. Physical geographers began adopting a different scientific approach. This approach relied on logical deductive reasoning, model building, experiments, and other quantitative techniques. This **Quantitative Revolution** was also associated with a change in the way that physical geographers studied the Earth and its phenomena. Researchers now began investigating the operating processes rather than merely reproting the descriptive facts associated with natural phenomena. Today, this quantitative approach is becoming even more common due to advances in software, computers, and other measurement technologies used in the field and laboratory to perform research.

The modeling of natural phenomena using a systems theory approach became an important component of many studies beginning in the early 1960s. Systems theory suggests that natural phenomena can be viewed as being composed of a number of parts that work together through some process to produce an outcome. The application of systems theory also allowed physical geographers to become more reductionist in their research approach without losing a connection to larger systems like the Earth or its four interacting spheres (atmosphere, lithosphere, biosphere, and hydrosphere).

In 1964, William Pattison published an article in the ***Journal of Geography*** that suggested that modern geography was composed of the following four academic traditions:

**Spatial Tradition** - the investigation of the phenomena of geography from a strictly spatial perspective.

**Area Studies Tradition** - the geographical study of an area on the Earth at either the local, regional, or global scale.

**Human-Land Tradition** - the geographical study of human interactions with the environment.

**Earth Science Tradition** - the study of natural phenomena from a spatial perspective. This tradition is of course physical geography.

The academic traditions described by Pattison are still dominant fields of geographical investigation. However, the frequency and magnitude of human mediated environmental problems have been on a steady increase since the publication of this notion. These increases are the result of a growing human population and the consequent increase in the consumption of natural resources. Because of mounting environmental problems, many physical geographers move away from theoretical studies. Instead, these scientists started applying knowledge common to their disciplines to find solutions to these problems. For instance, climatologists suggested that global warming was caused by the human activities that result in the emission of greenhouse gases into the atmosphere. Biogeographers argued that losses of biodiversity were mainly due to the conversion of ecosystems to agricultural fields and urban land-use. Geomorphologists identified the potential hazard associated building human settlements near earthquake faults. Hydrologists suggested that a number of human activities were responsible for the pollution of rivers, lakes, and groundwater.

The growth of physical geography as a discipline exploded in the 1970s. It was now becoming common for departments of geography in the USA, Canada, Australia, New Zealand, and in various European countries to have one or more faculty specializing in the study of climatology, geomorphology, biogeography, and hydrology. During the 1970s, we also see the establishment of remote sensing and Geographic Information Systems (GIS) as valuable tools for research in physical geography. At first these tools were mainly used to monitor natural and human constructed phenomena, to collect descriptive data, or to generate maps. But this trend quickly became less important as researchers began using these technologies with spatial statistics and to build interactive models of systems.

## The 21st Century

Physical geography in the 21st century has been characterized by the following key developments. First, advanced measurement technologies and information-processing capabilities are becoming more frequently used for gathering and processing data. As such, our planet is now being actively monitored by a number of satellites each with an array of sensors for gathering information about the changing nature of the Earth's atmosphere, biosphere, hydrosphere, and surface landscape. Further, the vast amount of data collected by these technologies no longer requires sophisticated processing by super-computers. Current standard personal computers now suffice!

Human population growth and a steady rise in resource consumption per capita have drastically increased the number of environmental issues in need of action. Some of the more important problems include global warming, acid deposition, stratospheric ozone depletion, ocean acidification, natural land-cover loss, biodiversity reduction, introduction of exotic species, and the alteration of biogeochemical cycles. As explained earlier in this discussion, physical geographers are well prepared intellectually to work on finding solutions to these serious problems facing our planet.

## Phenomena of Study in Modern Geography

We have so far learned that geography consists of at least two different sub-fields of knowledge with similar methodology: physical geography and human geography. **Table 1.1** helps to make the differences between these two sub-areas of geography even more apparent by describing some of the phenomena studied by each of these fields of knowledge. Knowing what kinds of things geographers study provides us with a better understanding of the differences between physical and human geography.

Geography is a discipline that integrates a wide variety of subject matter. Many areas of human knowledge can be examined from a spatial perspective. **Figure 1.4** describes some of the main sub-disciplines found within human and physical geography. Physical geography's primary sub-disciplines study the Earth's atmosphere (meteorology and climatology), animal and plant life (biogeography), physical landscape (geomorphology), soils (pedology), and waters (hydrology). Some of the dominant areas of study in human geography include: human society and culture (social and cultural geography), behavior (behavioral geography), economics (economic geography), politics (political geography), and urban systems (urban geography).

The graphic model in **Figure 1.4** indicates that the study of geography can also involve a holistic synthesis. Holistic synthesis connects knowledge from a variety of academic fields in both human and physical geography. For example, the study of the enhancement of the Earth's greenhouse effect and the resulting global warming requires a multidisciplinary approach for complete understanding. The fields of climatology and meteorology are required to understand the physical effects of putting additional greenhouse gases on the atmosphere's radiation balance. The field of economic geography provides information on how various forms of human economic activity contribute to the emission of greenhouse gases through fossil fuel burning and land-use change. Combining the knowledge of both of these academic areas

**TABLE 1.1** Some of the phenomena studied in contemporary physical and human geography.

| Physical Geography | Human Geography |
|---|---|
| Natural Hazards | Demography |
| Landforms | Settlements |
| Animals and Their Distributions | Transportation |
| Plants and Their Distributions | Recreational Activities and Tourism |
| Movements of Water | Religion |
| Atmosphere and Its Circulation | Political Systems |
| Rivers and Other Water Bodies | Social Traditions |
| Environment | Human Migration |
| Climate and Weather | Agricultural Systems |
| Oceans | Urban Systems |
| Soils | Economic Activities |

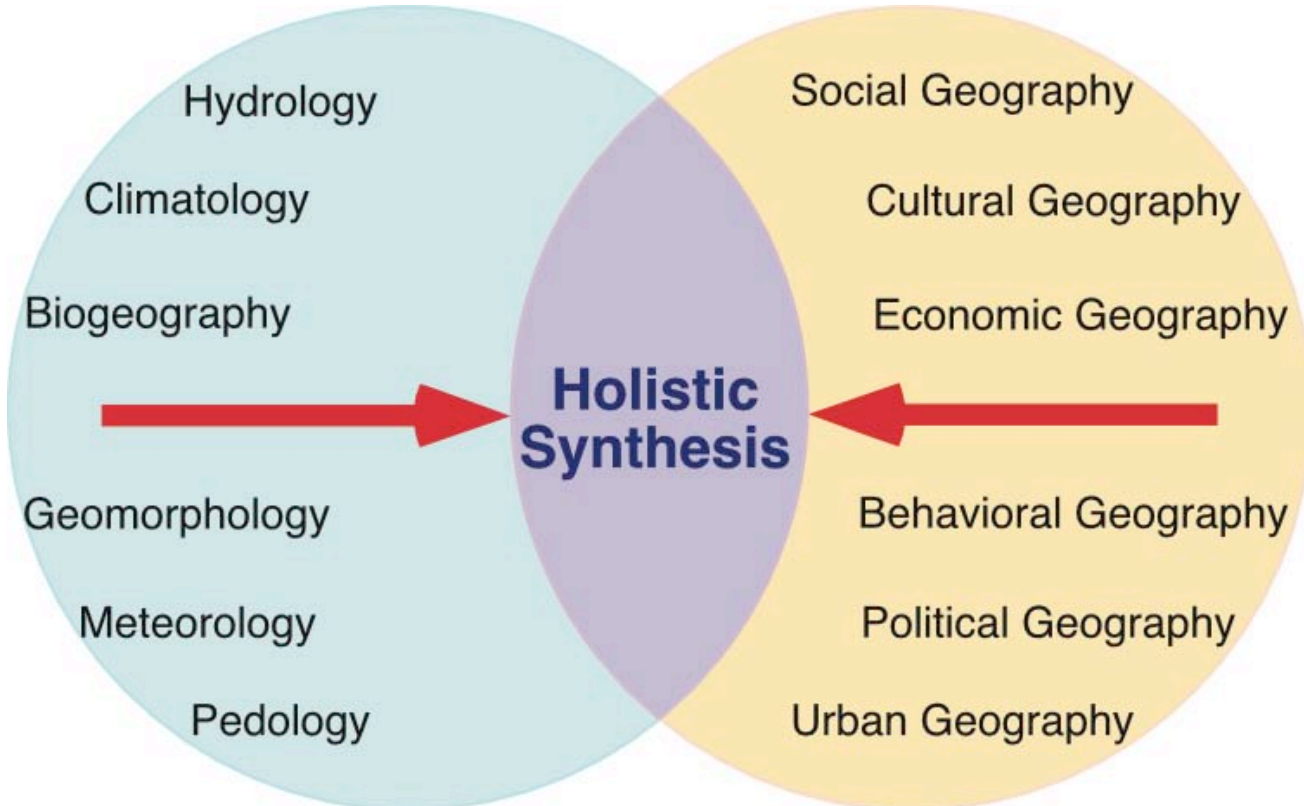


**FIGURE 1.4** Some of the major sub-disciplines of physical geography (left) and human geography (right) are shown. This illustration suggests that one of geography's major strengths is the holistic synthesis of knowledge from the various sub-disciplines for the purpose of understanding and problem solving. *(Image Copyright: Michael Pidwirny)*

gives us a more comprehensive understanding of why this serious environmental problem has developed.

The holistic nature of geography sets it apart from other forms of knowledge. Geography has the ability to see the big picture by connecting functional relationships that exist at various levels of spatial scale. These types of relationships are often not noticed by other fields of knowledge.

## DEFINITION OF PHYSICAL GEOGRAPHY

So far we have learned that physical geography examines and investigates natural phenomena spatially. We also described some of the key elements studied by the various specialists in physical geography (Table 1.1). Combining these two ideas, we can develop a more precise definition for physical geography. This definition suggests that **physical geography** examines the spatial patterns of weather and climate, water, soils, vegetation, animals, and landforms.

Physical geography also examines the inter-relationships of natural phenomena to human activities. This area of geography has seen very keen interest and growth in the last few decades because of the acceleration of human induced environmental degradation. Thus, physical geography's scope is much broader than the simple spatial study of nature. It also involves the investigation of how humans are influencing nature.

Individuals studying physical geography and other related earth sciences are rarely generalists. Most are in fact highly specialized in their fields of knowledge and tend to focus themselves in one of the following well-defined areas of understanding in physical geography:

**Geomorphology** - studies the various landforms on the Earth's surface.

**Pedology** - is concerned with the investigation of soils.

**Biogeography** - is the science that investigates the spatial relationships of life on our planet.

**Hydrology** - the field of knowledge that is interested in the study of water in all its forms.

**Meteorology** - studies the physical and chemical processes that operate in the atmosphere over short time spans.

**Climatology** - studies the effects of weather on life and examines the condition of the atmosphere over longer periods of time.

The above fields of knowledge generally have a primary role in introductory textbooks dealing with physical geography. Introductory physical geography textbooks can also contain information from other related disciplines including:

**Geology** – the scientific study of the Earth's composition, structure, geologic history, and the processes that influence our planet's interior and exterior.

**Ecology** - the investigation of the interactions between organisms and their environment.

**Oceanography** - the science that examines the biology, chemistry, physics, and geology of oceans.

**Cartography** - the field of knowledge that studies the various techniques for designing and constructing maps.

**Astronomy** - the science that describes the objects found in the universe and tries to understand the processes influencing celestial bodies and the cosmos.

Finally, both human and physical geography provide an important intellectual background for studying the environment. Webster's 11th Collegiate Dictionary defines **environment** "*... as the complex of physical, chemical, and biotic factors (such as climate, soil, and living things) that act upon an organism or an ecological community and ultimately determines its form and survival*". Many environmental studies/science programs offered by Universities and Colleges around the world utilize the information found in various geography courses to help educate their students about the state of our planet's environment.

## THE FOUR SPHERES

At the global level, physical geographers view the Earth as being composed of four different functioning parts: the atmosphere, the hydrosphere, the lithosphere, and the biosphere. Each of these spheres is often studied somewhat independently of each other. Consequently, the discussion in this textbook is organized according to this idea. A closer examination of the various phenomena that operate in each of these parts reveals that the spheres often interact with each other at various scales of function. Many of these interactions will be discussed as we proceed through the content of this textbook. It will also become quite apparent that modern humans are actively influencing a number of these interactions at local, regional, and even global scales.

### The Atmosphere

The **atmosphere** is the vast gaseous envelope of air that surrounds the Earth. Its boundaries are not easily defined (**Figure 1.5**). The atmosphere contains a complex mixture of gases and suspended particles that behave in many ways like fluids. Many of its constituents are derived from the Earth by way of chemical and biochemical reactions. The atmosphere is also the sphere where our planet's weather operates. Some of the important elements of the atmosphere include: temperature, precipitation, wind, pressure, and humidity.

### The Hydrosphere

The **hydrosphere** describes the nature of water on our planet (**Figure 1.6**). Water exists on the Earth in various stores. Some of the important stores include: the atmosphere, oceans, lakes, rivers, soils, snow, glaciers, and groundwater. Water is transferred from one store to another by way of evaporation, transpiration, condensation, runoff, precipitation, infiltration, and groundwater flow. Humans have greatly influenced the hydrosphere by altering the process of runoff to supply water for domestic, industrial, commercial, and agricultural needs.

### The Lithosphere

The definition of **lithosphere** used by most geoscientists suggests that it is the outer rigid layer of the

**FIGURE 1.5** The atmosphere is a thin layer of gases and airborne particles that exists above the Earth's solid surface. The atmosphere is also the place where our planet's weather occurs. *(Source: NASA)*

Earth's crust that floats on top of more plastic semi-liquid rock materials. For the purpose of this discussion on the Earth's spheres, we will define the lithosphere as the solid inorganic portion of the Earth (**Figure 1.7**). The lithosphere is composed of inorganic matter that organizes itself into definable units known as minerals and rocks. Physical geographers have been keenly interested in studying the landforms found on the surface of the lithosphere. Many of these studies have investigated the processes that determine how the various landforms form.

**FIGURE 1.6** The hydrosphere consists of all the water that is found on our planet. Some of the important stores of water include the ocean, the atmosphere, and lakes, rivers, snow, and glacier ice on the Earth's terrestrial surface. In the above image, we can see rain falling from a cloud in the atmosphere to the ground surface. *(Image Copyright: Michael Pidwirny)*

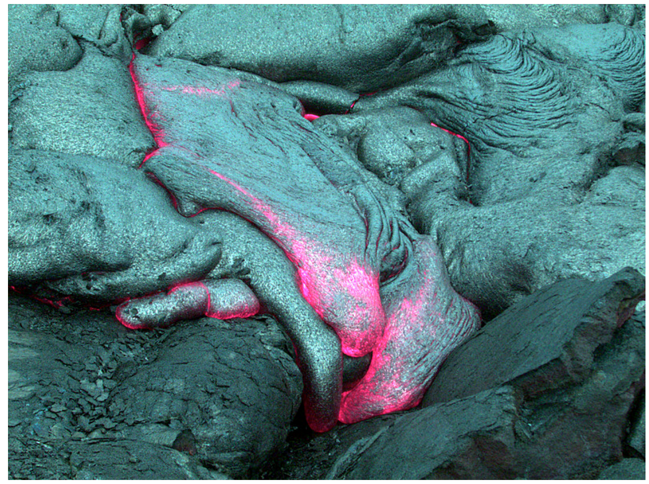

**FIGURE 1.7** The lithosphere is the solid portion of the Earth that is made of rock and minerals. In reality, only a thin layer of the lithosphere is cool enough to be solid. Beneath this crust, high temperatures and pressure causes the inorganic matter that makes up the lithosphere to melt. When this hot semi-liquid material seeps up to the Earth's surface we call it magma. The solidification of magma forms new minerals and rocks. *(Source: Wikipedia)*

### THE BIOSPHERE

The **biosphere** consists of all living things, plant and animal (**Figure 1.8**). This sphere is characterized by life in abundance, diversity, and clever complexity. Through evolution life has gained a variety of adaptations that allow it to occupy and survive in parts of the hydrosphere, atmosphere, and lithosphere. One form of life, humans, is now an important controlling force on the Earth. This domination is influencing other forms of life, the atmosphere, the hydrosphere, and the lithosphere in a variety of ways. Some of the human activities threaten the future quality of life for people and for the various plants and animals that also live on this planet.

## SCIENCE OF PHYSICAL GEOGRAPHY

Science is simply a way of acquiring knowledge about nature and the Universe. To practice science, one must follow a specific universal methodology. The central theme of this methodology is the testing of hypotheses. A **hypothesis** can be defined as a proposal intended to explain certain facts or observations that has not been formally tested. The overall goal of science is to better comprehend the world around us. Various fields of study, like physics, chemistry, biology, medicine and the earth sciences, have used science exclusively to expand their

**FIGURE 1.8** All of the living organisms found on our planet make up the biosphere. Through evolution life has gained adaptations to allow it to successfully survive even in the most extreme environments. *(Source: Wikipedia)*

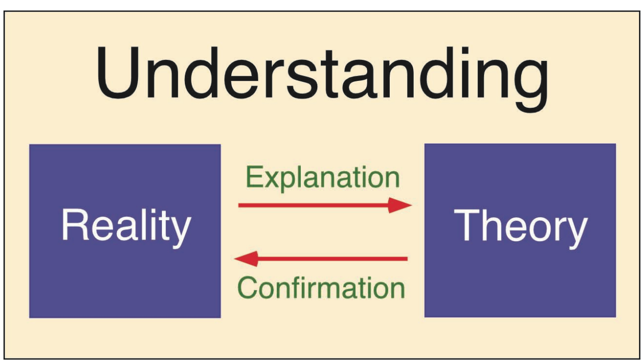


**FIGURE 1.9** Relationship between reality, theory, and understanding in science. This model suggests that we develop scientific theories to explain phenomena found in reality. Once a theory is established, it must be confirmed by re-examining reality to find contrary data. If contrary data is found, the theory is modified to include this new information and the confirmation process begins again. The process of validating theories is endless process because we can never assume that we have considered all possibilities. *(Image Copyright: Michael Pidwirny)*

knowledge base. Science allows its practitioners to acquire knowledge using techniques that are both neutral and unbiased.

The broadest, most inclusive goal of science is to understand (**Figure 1.9**). Understanding involves two interconnected processes: explanation and confirmation. Explanation is perhaps the most important basic goal of understanding. Explanation consists of explaining reality with a system of hypotheses, theories, and laws. Explanation may also relate observed phenomena to a system of empirical formulas, or link them to mechanisms that are hierarchically structured at both higher and lower levels of function. A **theory** can be defined as a collection of logical ideas that are used to explain something. The process of testing, refining, and re-testing hypotheses constructs theories. The nature of this confirmation process suggests that theories are rarely static

The process of explanation has two important facilitating tools: idealization and unification (**Figure 1.10**). Idealization may be considered to be the condensation of a body of empirical fact into a simple statement. In the process of condensation, some detail must be omitted and the processes and phenomena must be more simply abstracted. Idealization may also involve isolating particular phenomena from other aspects of the system of interest. For example, models explaining the operation of the human heart often exclude the fact that it is one of many organs operating in tandem in our body. A second aspect of explanation is the unification of apparently unrelated phenomena under the same abstract or ideal system of concepts.

Another minor goal of science is the confirmation of constructed models of understanding (also called theoretical model building). Confirmation is accomplished through hypothesis testing, prediction, and experimentation. These tools will be discussed in detail in the next section.

## The Hypothetico-Deductive Method

Francis Bacon (1561-1626), a 17th century English philosopher, was the first individual to suggest a universal methodology for science. Bacon believed that **scientific method** required an inductive process of inquiry. **Induction** involves the formulation of a theory after the analysis of gathered facts. In the 20th century, philosopher Karl Popper suggested that it is impossible to prove a scientific theory true by means of induction, because no amount of evidence assures us that contrary evidence will not be found. Instead, Popper proposed that the best way to

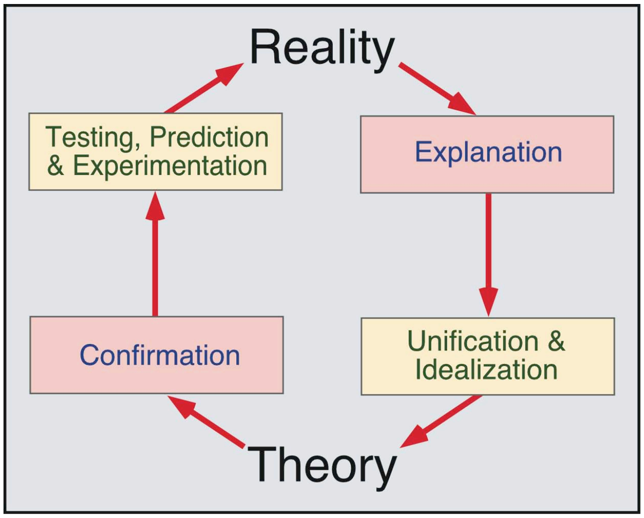


**FIGURE 1.10** Facilitating tools involved in explanation and confirmation. *(Image Copyright: Michael Pidwirny)*

do science is through deductive logic. **Deduction** involves stating a hypothesis first and then examining reality to find evidence to disprove the proposed idea. Popper termed the procedure of trying to disprove a proposed hypothesis **falsification**.

Researchers in physical geography normally try to falsify hypotheses through two means: prediction or experimentation. A **prediction** is a forecast or extrapolation from the current state of the phenomenon of interest. Predictions are most useful if they can go beyond simple forecasts. This can be accomplished through **computer models** that employ a network of mathematical relationships that describe how the phenomenon works under different scenarios. Computer models that evaluate the climatic effects of human modification of the Earth's atmosphere work in this way. An **experiment** is a controlled investigation designed to evaluate the outcomes of causal manipulations on some system of interest.

## SYSTEMS THEORY AND SCIENCE

In the 1940s, biologist Ludwig von Bertalanffy presented a novel method for studying natural phenomena called **systems theory**. Von Bertalanffy proposed systems theory to counter the growing trend of scientific reductionism. **Scientific reductionism** is a process where a scientist studies a particular phenomenon in isolation from the other phenomena that normally interact with it. The main advantage of this approach is that it allows one to clearly study the phenomenon without the background noise from outside cause and effect interactions. The disadvantage to this method is that phenomena normally function in an environment that includes interactions. By removing these interactions, we may only get a partial picture of how these phenomena actually work in the real world.

So what is a system? According to systems theory, a **system** is a group of parts that work together through some kind of process (**Figure 1.11**). Within its distinct boundary, a system has three kinds of properties called elements, attributes, and relationships. **Elements** are the kinds of things or substances making up the system. If our system of interest was a fresh water lake, then some of the elements that are typically found in this type of system would include water, fish, dissolved chemicals, insects, algae, and sediment at the lake bottom. **Attributes** are characteristics of the elements that can be perceived and measured. For the fish in a lake, the attributes may include quantity, length and weight of each individual, and species designation. **Relationships** are the cause and effect associations that exist amongst elements and between their attributes. Finally, the **state** of the system is defined when one or more of its properties (elements, attributes, and relationships) have a distinct value.

A **model** is a special type of system. There are two general types of models. Many models are simple, generalized representations of something in the real world. In these systems, details are left out for the purpose of quick and easy comprehension of how the phenomenon operates. For example, **Figure 1.11** models how energy flows from the Sun to Earth where it powers the various systems found in the atmosphere, hydrosphere, lithosphere, and the biosphere. Yet, we will discover further on in this textbook that this process is much more complex. The other type of model is also a generalization of reality but it has one extra feature. It has the ability to make predictions or forecasts of the future state of the system's elements or attributes. These predictions are possible because the cause and effect relationships that exist between the system's components are understood logically or mathematically. We sometimes refer to these systems as **mathematical models** or if the calculations are performed with a computer - computer models. Some of the problems that physical geographers have applied the use of computer models include: forecasting future weather and climates on our planet, determining the effect of drought on stream flow, and modeling the movement of insect pests in our forests (**Figure 1.12**).

Systems are sometimes visualized through illustrations. In these illustrations, elements and attributes can be sketched as simple component blocks or some other

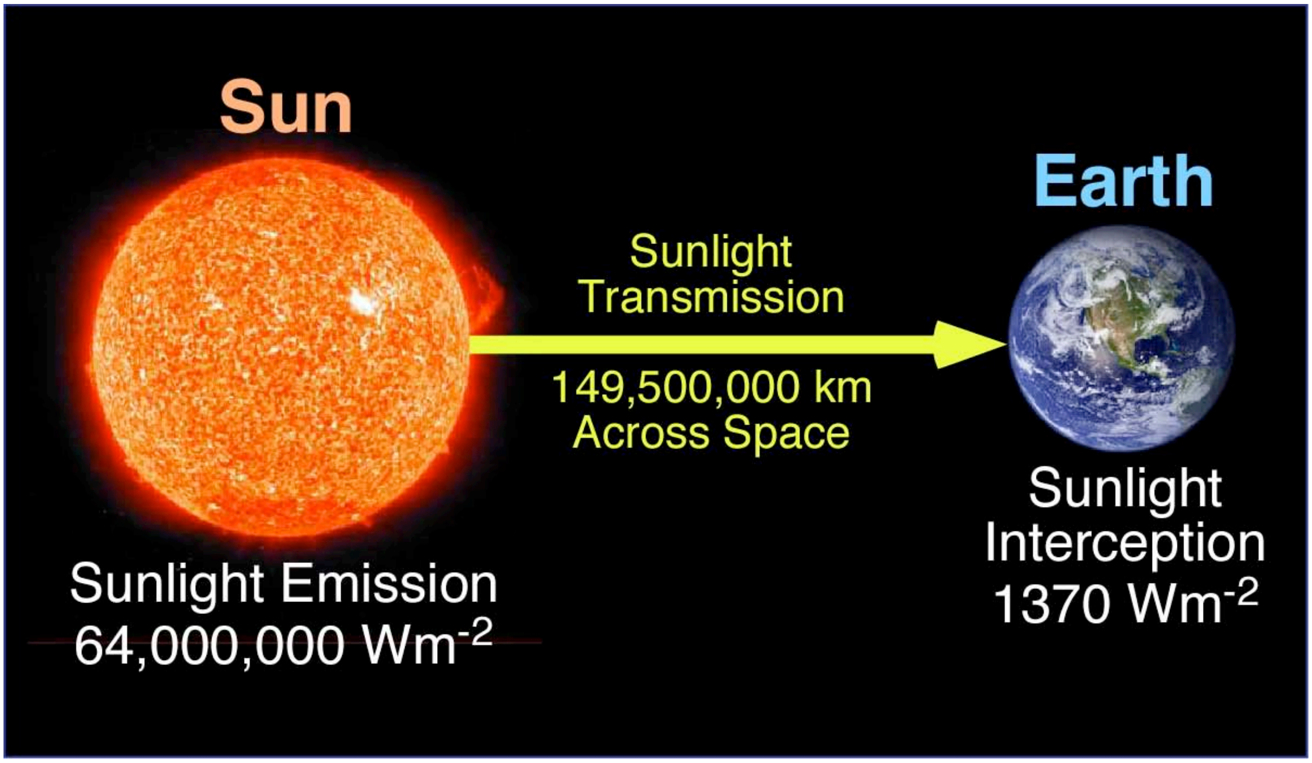


**FIGURE 1.11** This simple system visually describes the Earth's interception of sunlight generated by the Sun. *(Image Copyright: Michael Pidwirny)*

type of graphical representation. Processes that operate between elements and/or attributes are usually identified by some kind of connection drawn between these parts. Most of the graphic illustrations found in this textbook and other science books are examples of systems. Graphical systems are used in this textbook to improve the learning process for students. Graphical systems are very effective in explaining how various natural phenomena work because a good illustration can often be worth a thousand words!

Scientists have classified many types of systems according to the way they function. An **isolated system** is a system in which there are no interactions occurring outside its boundary layer. Such systems are common in laboratory experiments where chemical reactions are confined to test tubes or beakers. A **closed system** is slightly different from an isolated system. It does not allow for the transfer of matter into or out of its boundary. But, it does allow for the transfer of energy across its boundary. Our planet is essentially a closed system. It receives radiant energy from the Sun that is used to power an assortment of phenomena in the atmosphere, hydrosphere, lithosphere, and biosphere. This energy is subsequently returned to space as longwave emissions. As for matter, our planet is not involved with significant transfers of substances into or from outer space (only an extremely small amount of mass is added to our planet from meteorites and other small celestial bodies). In an **open system**, both matter and energy can cross the boundary of this entity. Most ecosystems are considered an open system (**Figure 1.13**). An **ecosystem** can be defined as the interaction of different biotic entities with each other and with abiotic components in some area of space. Energy primarily moves into ecosystems by way of incoming reception of sunlight and leaves by the emission of longwave radiation. Matter can transfer across an ecosystem's boundary by the migration or dispersal of organisms.

## System Hierarchy and Interconnections

One of the most important aspects of viewing natural phenomena as systems is the idea of hierarchical interconnectivity. At any functional level a system may be connected to a variety of other systems. Some of these connections could be to phenomena that exist at the same level of operation. Systems can also be connected to a number of smaller systems working within their various elements. And within these smaller systems there could be yet more minuscule systems working towards some other purpose. Thus, at any particular scale of function a system

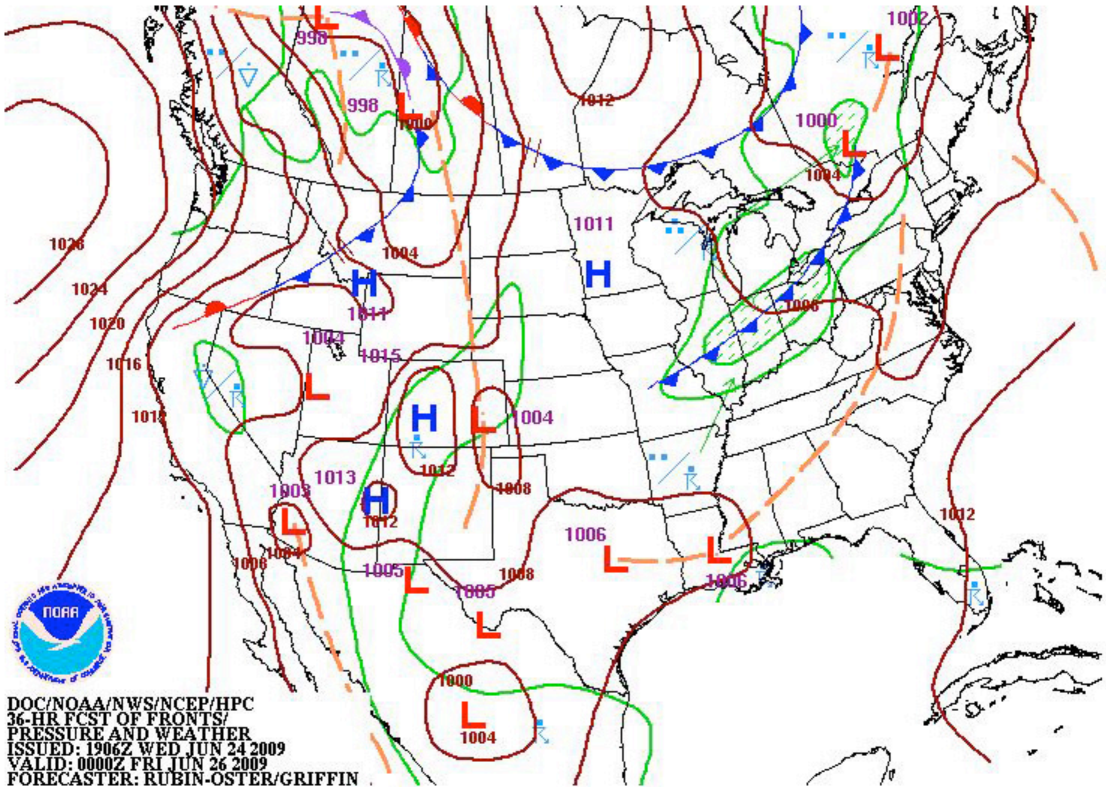


**FIGURE 1.12** 36-hour weather forecast for central North America. This forecast was mathematically modeled in a super-computer using data collected from many weather stations. *(Source: NOAA)*

is connected to other phenomena working at a variety of different scales. These connections are usually active in terms of cause and effect. As a result, the modification of one system's state may have effects that reverberate to systems at other functional levels. This idea is especially important when considered in the context of human manipulation of systems in the Earth's various spheres. Our modification of the Earth's climate through global warming may affect the position of the Earth's jet streams, or the number of hurricanes that form over the world's oceans, or the types of plants that you can grow in your garden.

A good example of a system within another system is the hierarchy of systems found in our Universe. Let us examine this system from top to bottom. At the highest level in this hierarchy we have the system that we call the cosmos or Universe. The elements of this system consist of galaxies, quasars, black holes, stars, planets, and other heavenly bodies. The current structure of this system is thought to have come about because of an enormous cosmic explosion and is controlled by gravity, weak and strong atomic forces, and electromagnetic forces. Around some stars in the Universe we have an obvious arrangement of planets, asteroids, comets, and other materials. We call these systems solar systems. The elements of this system behave according to set laws of nature and are often found orbiting around a central star because of gravitational attraction. On some planets, conditions may exist for the development of dynamic interactions between the hydrosphere, lithosphere, atmosphere, or the biosphere.

We can define a planetary system as a celestial body in space that orbits a star and maintains some level of dynamics between its lithosphere, atmosphere, and hydrosphere. Some planetary systems, like the Earth, can also have a biosphere. If a planetary system contains a biosphere, dynamic interactions will develop between this system and the lithosphere, atmosphere, and hydrosphere. These interactions can be called an environmental system. Environmental systems can also exist at smaller scales of size. A single flower growing in a field could be an example of a small-scale environmental system.

The Earth's biosphere is made up of small interacting entities called ecosystems. In an ecosystem, populations of species group together into communities and interact with each other and the abiotic environment. The smallest living entity in an ecosystem is a single organism. An organism is alive and functioning because it is a biological system. The elements of a biological system consist of cells and larger

**FIGURE 1.13** This pond ecosystem has a obvious boundary located where water meets land and the atmosphere. Despite the presence of this boundary it is not an isolated system. Actually, this system is quite open to the transfer of energy and matter across its boundary. For example, energy from the Sun enters this ecosystem when sunlight is absorbed by a layer of water near the pond surface and converted into heat energy. This heat energy is then transferred throughout the pond by the processes of conduction and convection. As for matter, water moves in and out of the pond via runoff, precipitation, groundwater flow, and evaporation. *(Image Copyright: Darlene Heckl)*

structures known as organs that work together to produce life. The functioning of cells in any biological system is dependent on numerous chemical reactions. Together these chemical reactions make up a chemical system. The types of chemical interactions found in chemical systems are dependent on the atomic structure of the reacting matter. The components of atomic structure can be described as an atomic system.

## Systems and Equilibrium

Earlier in this discussion the concept of system state was introduced. System state was defined as the measurement of the current condition of an element, attribute or relationship within a system. If these measurements are recorded over time we may notice that particular patterns of values emerge. These patterns also represent the average condition or **equilibrium** of this component. Many different types of equilibrium have been defined (**Figure 1.14**). A **steady-state equilibrium** occurs when the average value of a system component maintains the same trajectory over time. In other words, the average condition of the system's property remains the same over a particular time period. The opposite of steady state condition is a **dynamic equilibrium**. This condition occurs when the average states continually change their values over time. **Thermodynamic equilibrium** describes a condition in a system where the distribution of mass and energy becomes more disordered and unavailable with time. Our Universe is moving towards this state because energy is being continually transferred into less useful forms. A **static equilibrium** occurs when the value of a system's property remains unchanged over time.

The state of a system's properties is also influenced by disturbances. A **disturbance** can be defined as some type of input that upsets the usual processes taking place in a system. For example, a fire would upset a number of natural processes taking place in a grassland. Plant production of organic matter would be reduced because of the plant deaths. This in turn would cause grazing animals to go hungry, leading to declines in the size of species populations. Further, nutrient elements once locked up in organic matter would be converted into ash and gas. Components of a system can recover from a disturbance in two ways. The property could return to the same equilibrium that existed before the disturbance. This condition is known as a **stable equilibrium**. Or the system could return to a new equilibrium after disturbance. This situation is called an **unstable equilibrium**.

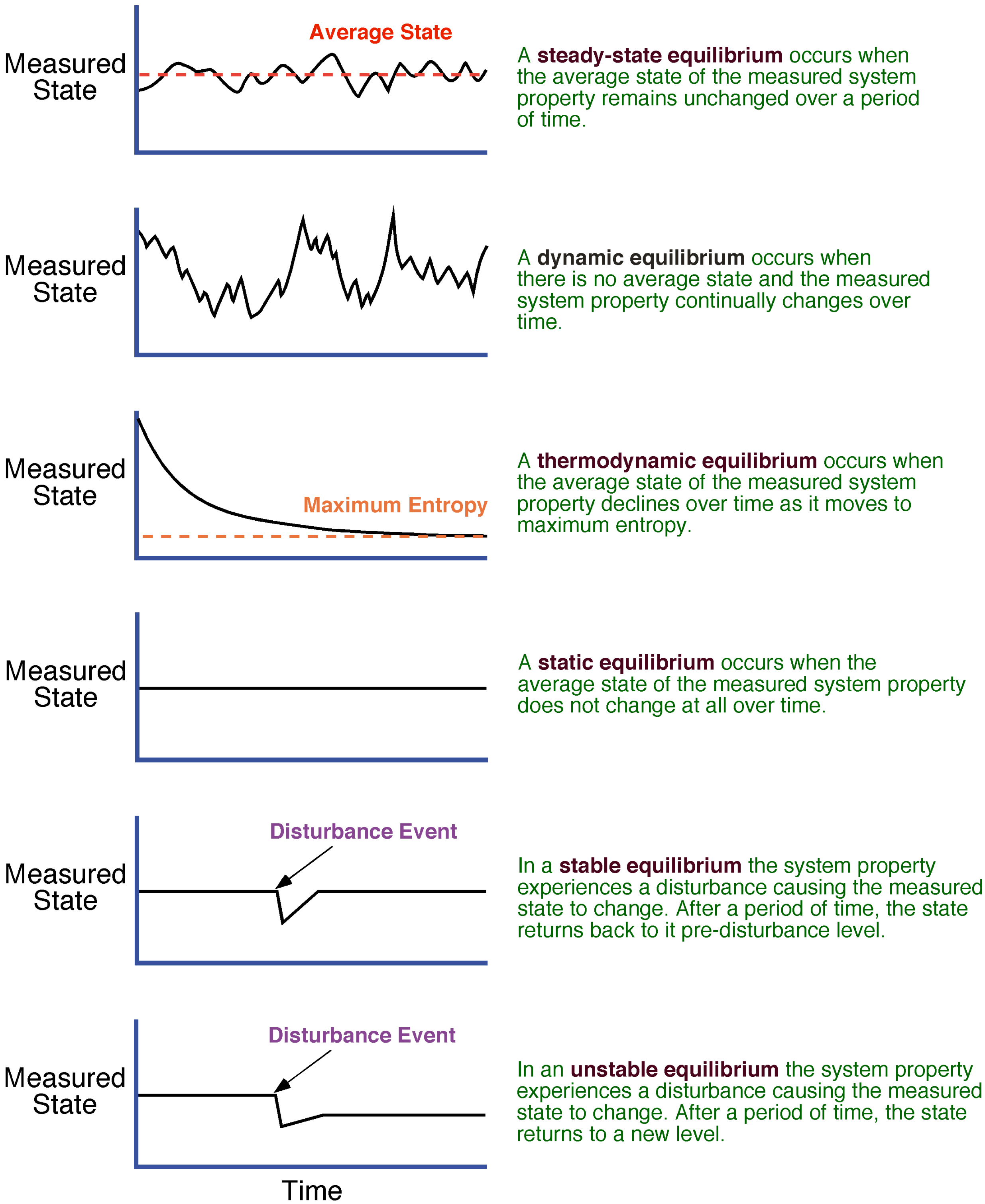


**FIGURE 1.14** The various types of system equilibrium. *(Image Copyright: Michael Pidwirny)*

## CHAPTER SUMMARY

- This chapter begins by examining the nature of geography and physical geography. A historical approach is used to discuss the evolution of geography and physical geography as disciplines.
- We then established working definitions for geography, physical geography, human geography, and physical geography's sub-fields.
- The relationship between physical geography and other earth sciences and environmental science is discussed.
- It is then suggested that the curriculum of physical geography provides important knowledge for understanding and rectifying environmental problems.
- At the global scale we can suggest that the Earth consists of four functioning units: the atmosphere, the hydrosphere, the lithosphere, and the biosphere.
- The atmosphere can be simply defined as the layer of gases that surrounds the surface of the planet.
- All of the waters of the Earth make up the hydrosphere.
- The lithosphere can be defined as the solid portion of the planet that is composed of minerals and rocks.
- All the living organisms that inhabit our planet make up the biosphere.
- Physical geographers use the scientific method to gather knowledge about the workings of the natural world.
- Before the turn of this century, scientific method mainly involved the process of inductive logic.
- Induction involves gathering data from nature and then constructing a theory. Someone using this method may be fooled into thinking they had collected all of the data that were available. However, because the Universe is infinite no amount of evidence can assure us that contrary evidence will not be found.
- Philosopher Karl Popper suggested that the correct method for science would involve logical deduction.
- Deduction involves the process of hypothesis falsification. In this process, you develop a hypothesis first and then try to find evidence that contradicts that statement. Of course in the real world, one must start the process of conceptual model building by collecting data first (induction).
- Scientists use systems theory to understand how things work. Systems theory suggests that you represent natural and human-made phenomena as a set of interrelated components that work together to accomplish a particular process.
- Systems tend to have similarities in the way they work. Within their defined boundaries, systems contain three types of properties: elements, attributes, and relationships.
- Elements are the things that make up a system. Attributes are the perceived characteristics of the elements. Relationships are descriptions of how the various elements (and their attributes) work together through some kind of process.
- Scientists have classified a number of different system types. These types include: isolated systems, closed systems, open systems, models, mathematical models, computer models, and ecosystems.
- We often think about systems in an isolated fashion. However, most systems have hierarchical connections and structure. When examining systems we are most aware of connections that exist to other systems at the same functional scale. Connections can also exist to systems that exist at smaller or larger scales of nature.
- It is very important to recognize that systems generally do not exist in isolation and that changes to one particular system may echo changes to other systems in the hierarchy.
- Equilibrium can be defined as the average state of a system as measured through one of the system's properties. Scientists have defined six different types of equilibrium.

## IMPORTANT TERMS

**Area Studies Tradition**
**Astronomy**
**Atmosphere**
**Attribute**
**Biogeography**
**Biosphere**
**Cartography**
**Climatology**
**Closed system**
**Computer model**
**Deduction**
**Disturbance**

**Dynamic equilibrium**
**Earth Science Tradition**
**Ecology**
**Ecosystem**
**Element**
**Environment**
**Equilibrium**
**Experiment**
**Falsification**
**Geography**
**Geology**
**Geomorphology**
**Human geography**
**Human-Land Tradition**
**Hydrology**
**Hydrosphere**
**Hypothesis**
**Induction**
**Isolated system**
**Lithosphere**
**Mathematical model**
**Meteorology**
**Model**
**Oceanography**
**Open system**
**Pedology**
**Physical geography**
**Prediction**
**Quantitative Revolution**
**Relationship**
**Scientific method**
**Scientific reductionism**
**Spatial Tradition**
**Stable equilibrium**
**State**
**Static equilibrium**
**Steady-state equilibrium**
**System**
**Systems theory**
**Theory**
**Thermodynamic equilibrium**
**Unstable equilibrium**

## CHAPTER REVIEW QUESTIONS

1. How does physical geography differ from human geography?
2. Define physical geography.
3. What are some of the sub-fields of physical geography? What do they study?
4. How does physical geography relate to the study of environmental issues?
5. Describe Pattison's four traditions of geography.
6. What was the quantitative revolution?
7. What is science? What are its goals?
8. Why is deduction a preferred method for carrying out science?
9. What tools are used to test scientific hypotheses?
10. What is a system? How do we use them in the process of understanding how natural phenomena function?
11. Define the three kinds of properties (elements, attributes, and relationships) found in systems.
12. What is an equilibrium? Describe some of the different types of equilibrium that exist in nature.

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