

Elements of Physical Geography

3rd edition

Strahler / Strahler



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Preface

Elements of Physical Geography, Third Edition, is written for use in one-semester and one-quarter survey courses. Both content and structure are designed for students who are following general education programs in nonscience fields and who need only an overview of global physical environments. In keeping with this objective, we stress important concepts and basic facts, treating them descriptively and minimizing the use of technical terms. Emphasis is on ways in which the physical environment influences human activity, both directly and indirectly. These influences act through climate, soils, vegetation, and landforms.

If we are to make physical geography more than a mere collection of science topics, and if we are to give students an insight into the nature and goals of professional geography, we must emphasize spatial distribution of physical environmental variables and their interactions. Thus, we stress the global patterns of climate, landforms, soils, and vegetation; we explain these patterns as simply as possible in terms of natural processes.

Two contemporary trends in physical geography are emphasized. One trend is toward identification and analysis of natural flow systems of energy and matter, including both physical systems and ecosystems. We seek to link physical and organic processes through the concept of cycling of energy and materials within ecosystems. To analyze problems of world food resources, geographers must integrate their knowledge of physical systems with the ecologists' knowledge of ecosystem dynamics. A second trend is toward a climatology geared more closely to the soil-water balance and the availability of soil water to plants. Following this trend allows us to evaluate freshwater resources of the lands explicitly in terms of the annual and

seasonal water surplus or water deficit. Emphasizing the soil-water balance also helps in understanding the modern Comprehensive Soil Classification System and Soil Taxonomy, which use soil-water regimes as a major factor in classifying soils and differentiating soil orders and suborders.

Physical geography is closely involved with analysis of human impact on the environment. A trend toward deeper involvement is understandable, because physical geography integrates most of the diverse factors contributing to environmental changes. Wherever relevant, we include material on the impacts of human activities on the environment and on resources that are renewable through inorganic and organic cycling of energy and matter.

The Introduction emphasizes the nature and goals of physical geography, using two brief case studies to illustrate relationships between humans and their environment. The first nine chapters closely follow the order and content of previous editions and are intended to cover processes and forms within the atmosphere and hydrosphere. This group ends with Chapter 10, Runoff and Water Resources, which has been moved to this position because it completes the hydrologic cycle begun in the preceding chapter on the soil-water balance.

Because of increased emphasis on flow systems of energy and matter, a special section on that topic has been placed at the end of Chapter 2. It serves as a science review and explains the new graphic format for displaying models of flow systems by means of symbols based on Howard T. Odum's pioneer work on ecosystem energetics. Throughout later chapters, system diagrams of this type are introduced to show models of several important flow systems of energy and matter, including both open and closed systems.

Significant additions to these early chapters are short descriptions of useful forms of energy—solar energy, wind power, and current power. In later chapters, other natural forms of energy are described—hydropower, fossil fuels, geothermal energy, tidal power, and biomass energy.

Our descriptive climate classification system, used in Chapter 8, remains unchanged, but we have transferred from an appendix to this chapter the full treatment of the Köppen system, together with the world map of Köppen climates. The newer system of climate classification based on the soil-water balance is presented in Chapter 9, where it provides a basis for the modern treatment of soil-forming processes and soil taxonomy covered in later chapters.

A major change in this edition is a reorganization of chapters in the second half of the book. In response to the advice of reviewers, we have moved the chapters on soils, ecosystem dynamics, and natural vegetation to a position following the chapters that deal with geology and geomorphology. This change has the advantage of covering mineralogy, mineral alteration, and parent soil materials before they are applied to soil-forming processes, soil classification, and nutrient cycling by plants. Further, the prior study of landforms shaped by the various agents of denudation gives the student an understanding of a major controlling factor in the development of soils and the differentiation of habitats. The chapter order now conforms with that found in the Second Edition of *Modern Physical Geography* (1983) and makes possible easy reference to that work for additional information on any given topic.

A major new improvement in the treatment of global geology is the expanded and modernized text on plate tectonics in Chapter 12. New block diagrams and structure sections explain geologic activities along plate boundaries, thereby increasing the power of the student to interpret major global topographic features, such as alpine and volcanic chains, island arcs, passive continental margins, and rifted areas within the continental lithosphere. Material on volcanic and tectonic activity and landforms has been placed in a separate chapter (Chapter 13). Here the principles of plate tectonics are called on to interpret

tectonic features in terms of collision and continental rifting, while the global distribution of earthquakes is explained in terms of plate boundaries. Chapters on geomorphology are similar in most respects to those of the previous edition, but the chapter on glacial landforms (Chapter 18) has been partly rewritten and somewhat expanded to include a modern view of the late-Cenozoic Ice Age and its possible causes.

The final two chapters, dealing with a system of global environmental regions, are little changed from the previous edition. In establishing the concept of a global environmental region, we not only perform an integrative function that is the hallmark of geography, but we also provide physical geography with a useful purpose in the management of human affairs. An environmental region, based primarily on a single climatic regime or biome, is endowed with a unique combination of soils, vegetation, hydrologic system, and geomorphic process. These factors are brought together in the description of each environmental region, together with an evaluation of the opportunities and restraints that the physical environment imposes on human activity and agricultural productivity. The concept of global environmental regions can thus provide a base for studies of environmental management.

The continued use of full color throughout the book in photographs, maps, graphs, and diagrams, despite greatly increased production costs, allows us to maintain maximum effectiveness of presentation in all areas. To keep the book price in a reasonable range, we have introduced design changes that tend to reduce the number of pages. The Postscript of the previous edition has been eliminated, with transfer of some of its parts to the final chapters. The Glossary remains complete and includes all technical terms in the text.

We acknowledge with thanks the contribution of a large group of geography instructors who completed a detailed publisher's questionnaire containing our proposals for revision of *Elements of Physical Geography*. Numerous comments and suggestions attached to the questionnaire by the respondents focused our attention on a wide range of possibilities for improving the text. With such broad-based guidance and support we

have been able to produce a revised edition that we hope will serve the needs of the large majority of physical geography instructors.

A Note on Sexism in Textbooks

Guidelines issued by publishers call attention to the need to avoid sexist expressions in textbooks. Sexism in its broader sense means any arbitrary stereotyping of males and females by reason of their gender. Except in those cases where the work of an individual geographer is cited, we have been careful to avoid using either feminine or masculine pronouns.

The word *man* is now regarded by many as closely associated with a male individual and is no longer broad enough in meaning to be applied to persons of either sex or to the human race. We therefore limit our use of

the word to specific references to *Homo sapiens*. Always capitalized, *Man* is the English translation of the Latin name of the species. In that context, the use of *Man* is no more sexist than, for example, *American*, *Canadian*, or *Navajo*, all of which are proper names for groups of people including both sexes. We avoid such modifiers as *man-made* and *man-induced*.

We use *humans* to denote groups of individuals of the species *Homo sapiens*. Derived from the Latin *humanus*, *human* is accepted as nonsexist because it has a different root from *man* (Anglo-Saxon, *mann*). As an adjective, *human* sees frequent use in environmental topics (e.g., *human activity*, *human impact*).

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Introduction

The Human Environment

The life layer The focus of physical geography is on the life layer, a shallow zone at the surface of the lands and oceans.

Inorganic earth realms The life layer draws its qualities from three inorganic earth realms—atmosphere, hydrosphere, and lithosphere.

The biosphere The life layer includes most of the world's organic life, representing the biosphere.

Environmental regions Within the life layer of the lands we recognize distinct environmental regions, each with its special life-supporting qualities.

Shuffling quickly through the chapters of this book, pausing now and then to look at illustrations and read a few figure captions or some lines of text, you may be tempted to ask “Isn't physical geography simply a collection of excerpts from several of the earth sciences and life sciences?” You may have noticed that the chapter on storms (Chapter 7) looks as if it belonged in a textbook of weather science (meteorology). Our section on volcanoes in Chapter 13 could have been taken from a textbook of geology. Our description of the food chain in a salt marsh (Chapter 21) may seem to have been lifted right out of a biology textbook.

If these are your first impressions of the makeup of physical geography they are at least partly correct, but they are also incomplete. Some important basic concepts of physical geography set it apart from a mere collection of natural science topics. Let us first find out what is really unique

about physical geography and how it fits into a geographer's view of the meaning of modern geography and the objectives that geographers are trying to reach.

Modern geography is deeply involved with the study of ways in which human beings and their institutions are spread over the surface of the earth. Because many human activities are influenced by the physical environment in which they take place, the study of physical geography is a key to understanding the different cultural patterns that have evolved over many centuries in habitable areas of the earth.

The Human Habitat

The lands of the earth comprise the habitat of the human species and all other terrestrial forms of life. The *habitat* of any plant or animal is the physical environment in which it is most likely to be found. Physical

geography brings together and interrelates the important elements of our physical environment that make up the human habitat. While emphasizing features of the environment that are most important to human survival, physical geography also deals with the environments of other life forms—both plants and animals—for we are dependent on them for food.

The Life Layer

The focus of physical geography is on the *life layer*, a shallow zone of the lands and oceans containing most of the world of organic life, or *biosphere*. Quality of that life layer is the major concern of physical geography. By quality we mean the sum of the physical factors that make the life layer habitable for all forms of plants and animals, but most particularly for the human species.

The quality of the physical environment of the land is established by factors, forces, and inputs coming both from the atmosphere above and the solid earth below. The *atmosphere*, a gaseous shell surrounding the solid earth, dictates climate, which governs the exchange of heat and water between atmosphere and ground. The atmosphere also supplies vital elements—carbon, hydrogen, oxygen, and nitrogen—needed to sustain all life of the lands.

The solid earth, or *lithosphere*, forms the stable platform for the life layer and is also shaped into landforms. These relief features—mountains, hills, and plains—bring another dimension to the physical environment and provide varied habitats for plants. The solid earth is also the basic source of many nutrient elements, without which plants and animals cannot live. These elements pass from rock into the shallow soil layer, where they are held in forms available to organisms.

Water, another of the essential materials of life, permeates the life layer, the overlying atmosphere, and the underlying solid earth. In all its forms, water on the earth constitutes the *hydrosphere*. Our study of physical geography can be described in the broadest of terms as a study of the atmosphere, hydrosphere, and lithosphere in relation to the biosphere.

Environmental Regions

Acting together, the inputs of energy and materials into the life layer from atmosphere and solid earth determine the quality of the environment and the richness or poverty of organic life it can support. Thus we can recognize *environmental regions*, each with its particular qualities for life support.

A given environmental region usually has certain definite locations on the globe in terms of latitude and continental position. It has a characteristic combination of soil type and native plant cover and offers a certain set of opportunities for the development of vital supplies of fresh water and food.

Some environmental regions are richly endowed with water and food; others are very poorly endowed. The poorly endowed environments are too cold, too dry, or too rocky to support much life. A major goal of physical geography is to evaluate each environmental region in terms of its life-support capacity.

Our Impact on the Environment

An understanding of physical geography is vital to planning for survival of the earth's rapidly expanding human population. Survival will not only depend on how much fresh water and food is available, but also on protecting the environment from forms of pollution and destruction that will reduce the capacity of the land to furnish those necessities. Here we encounter another of the important goals of physical geography: to evaluate the impact of human activities on the natural environment.

Physical geography has always been at the heart of environmental studies, because physical geography is strongly oriented toward understanding how the natural environment shapes and is shaped by the world's expanding population.

A Plan for Study

Our plan of study of physical geography is first to take a broad view of our planet as a sphere bathed in the sun's rays. We then

examine the atmosphere and oceans and learn how they gain and lose energy from the sun's rays. Following a study of the interactions between these gaseous and liquid layers we can evaluate global climate and water resources so vital to life on earth.

Next, the solid earth occupies our attention as we review geological principles essential to an understanding of major features of the earth's crust. We then investigate the configuration of the earth's land surface—its landforms and the processes that shape them. Now the stage is set for the role of organic activities in the biosphere; these strongly influence the soil layer, which supports the natural vegetation of the lands.

In our final chapters, all of the ingredients of physical geography are brought together in a review of environmental

regions of the globe. As we assess the life-support capabilities of each region, physical geography takes on new meaning and becomes a realistic base on which to build new plans for human survival.

Before beginning the systematic treatment of physical geography, we present two case studies to illustrate the nature of geography. The first case takes us back two centuries into American history, for it deals with the impact of farming on the land in colonial and postrevolutionary times on the eastern seaboard. The second case study deals with a foreign land in modern times; it tells of drought, famine, and death in a harsh environment in North Africa. Both cases illustrate how the physical environment of a region modifies human activities and how, in turn, those activities modify the environment.

Trouble at Mount Vernon — a Farm in Distress

As the wave of American Bicentennial celebrations recedes farther into the past, many romantic notions about the successes of our founding fathers remain in our minds. We visualize George Washington, retired happily on his Virginia estate Mount Vernon, reaping a richly deserved bounty from expansive farmlands under his personal supervision. We picture Thomas Jefferson at Charlottesville, managing his fields from his eyrie atop Monticello, while at the same time keeping a telescopic sight on his brainchild under construction, the new campus of the University of Virginia. These romantic visions fade under reality when we learn that fertility of farmlands in the colonies was declining rapidly, even as the new nation was struggling to stay alive. Ignorance of a simple point of soil science was responsible—acid soils need lime.

Without lime to correct soil acidity, essential nutrients for healthy crop growth cannot be retained in the soil, even though natural fertilizers are added. We read that George Washington conserved animal manure to spread on his fields, and that he had his field hands bring rich mud from creeks and marshes to spread on the soil to bring in a new supply of nutrients. A modern historian, Avery Craven, an authority on the agricultural history of that region, tells us that in 1834, 35 years after Washington's death, a visitor to Mount Vernon declared that "a more widespread and perfect agricultural ruin could not be imagined."

Another American, Edmund Ruffin (1794–1865), is credited with solving the mystery of failing agricultural fertility of the eastern seaboard. Ruffin owned lands at Coggins' Point on the coastal plain of Virginia. As with others, his land was rapidly declining in crop yields in the early 1800s. He tried many experiments to stop the decline, but application of manure had little effect and clover would not grow to enrich the soil. Quite by chance, Ruffin obtained a copy of Davy's *Agricultural Chemistry*, published in 1813. Despite Ruffin's lack of formal education in science, he was quick to grasp the significance of one statement: "any acid matter . . . may be

ameliorated by application of quicklime."

So it came about that on a February morning in 1818, Ruffin directed his field hands to haul marl from pits in low areas of his lands. (Marl is a soft lime mud that occurs widely as sedimentary strata on the eastern coastal plain.) The workers spread two hundred bushels of marl over several acres of newly cleared ridge land of poor quality. In the spring, Ruffin planted this area in corn to test the effect of the marl. In the words of historian Avery Craven, this is what happened: "Eagerly he waited. As the season advanced, he found reason for joy. From the very start the plants on marled ground showed marked superiority, and at harvest time they yielded an advantage of fully forty per cent. The carts went back to the pits. Fields took on fresh life. A new era in agricultural history of the region had dawned."* In 1832, Ruffin published his findings in a work titled *An Essay on Calcareous Manures*. His advice was outspokenly opposed, but time showed him to be right.

A geographer, reading this brief anecdote in history, will not be satisfied with the simple statement that the use of lime saved the agricultural resources of the eastern seaboard. The colonists who settled this region were largely from England, where their ancestors had farmed continuously and successfully for centuries, using the land for growing grains for their food and forage for their dairy animals. Like all farmers of Western Europe these colonists knew the necessity of applying animal manure as a soil fertilizer. What, then, was different about the physical environment of the American seaboard that resulted in rapid deterioration of the soils?

A geographer thinks first about the character of the American climate and soil and the geologic history of the landscape. Physical geography can demonstrate that a unique combination of these basic factors was responsible for the near-disaster that beset the American agriculturists. Soils over much of northwestern Europe were formed on freshly ground mineral matter left by the great ice sheets; nutrients needed by

* Avery Craven (1932), *Edmund Ruffin, Southerner*. D. Appleton and Co., New York, p. 55.



Harrowing the soil, sowing the seed. (New York Public Library. Picture Collection.)

crops are abundant in those soils. In contrast, upland soils of the eastern seaboard from Virginia to Georgia have been continually exposed to a leaching process in a mild, moist climate for tens of thousands of years. These soils have lost the ability to generate adequate quantities of mineral nutrients. Throughout this book we will explain the factors of climate, soils, and geologic history that bear on this case. In the final chapter, we will summarize our conclusions from a geographer's point of view.

Data Source: Emil Truog (1938), Putting soil science to work, *Journal of the American Society of Agronomy*, vol. 30, pp. 973-985.

Drought in the Sahel—the Sahara Desert Creeps Southward

Several West African nations lie in a perilous climatic belt called the Sahel. Because this belt lies along the southern border of the great Sahara Desert of North Africa, it is also referred to as the sub-Sahara region. Seven countries occupy much of the Sahel in western Africa: Senegal, Mauritania, Mali, Upper Volta,

Niger, Nigeria, and Chad. All these countries were struck a severe blow by drought, which began in 1968, became particularly severe in 1971 and 1972, was a major human catastrophe by 1974, and then ended in 1975.

The drought zone of the Sahel is, for the most part, a tropical grassland. It has a feast-or-famine climate. There is a short rainy season when the sun rides high in the sky (June, July, August), but a long dry season when the sun is low in the sky (November through April). To the north lies year-round drought of the Sahara Desert; to the south is a savanna region having a much longer wet season with much heavier rainfall. Drought in the Sahel means a dearth in the annual rains on which the growth of grasses depends. Two groups of humans live on the natural resources of the Sahel: nomadic herders and grain farmers. Both groups depend on the annual rains to turn the landscape green, rejuvenating the grasses on which their cattle graze and supplying the soil moisture needed for the annual crop of grain. When the rains fail to appear, there are no grain crops to harvest and the cattle starve for lack of forage.

Water in another form is vital to people