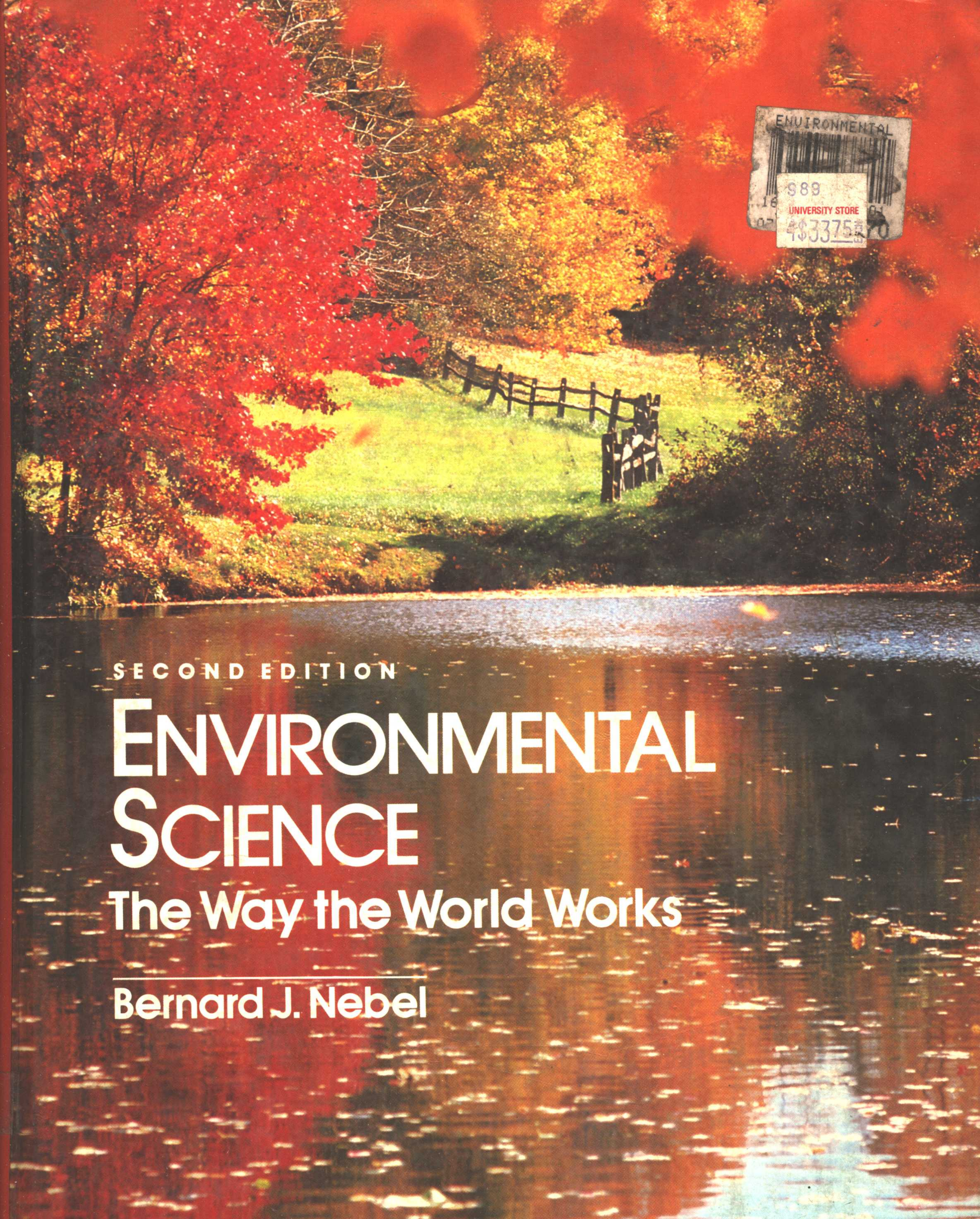

SECOND EDITION

ENVIRONMENTAL SCIENCE

The Way the World Works

Bernard J. Nebel

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Bernard J. Nebel *Department of Biology, Catonsville Community College*

with editorial assistance by Edward J. Kormondy, *University of Hawaii*
with writing assistance by Nancy K. Minkoff, *free-lance journalist, Bethesda, Md.*

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PREFACE

The theme and objective of the second edition of *Environmental Science: The Way the World Works* is to: (1) develop an understanding of the principles underlying the support and maintenance of all ecosystems; (2) show how our management (or lack of management) of the human ecosystem, in many cases, is counter to these principles, and how environmental problems, if not tragedies, occur as a result; (3) show how solutions to environmental problems lie in the direction of recognizing ecological principles and managing our human systems accordingly.

While the first edition of *Environmental Science: The Way the World Works* was very successful, the second edition has been entirely rewritten and to some extent reorganized, as well as updated, to achieve the objectives even more fully. The systematically organized, easy-to-read style suitable for the typical nonscience, freshman student has been maintained. Additionally, the "bulky" chapters of the first edition have been divided into two or more separate chapters. Then related chapters are grouped into six parts, each with an introductory overview. This has been done to increase the focus on individual topics and issues, and to enable more flexibility in teaching. An introductory chapter explaining how scientific facts, principles, and theories are derived, and their value and limitations in solving problems has been added. Finally, *Environmental Science: The Way the World Works* has been given an attractive, four-color design with many new photographs and line drawings.

Special effort has been made to present each topic in the context of our developing understanding of the issue. Our recognition of the problem, actions that have been taken, and their relative success or failure is given as a basis for discussion of present and future courses of action. The importance of political activism in attaining desired ends is stressed.

A SYNOPSIS

Part I *(Chapters 1 to 4)* develops the concepts of what ecosystems are, how they function, how they maintain (or lose) stability, and how they evolve. Greater than usual attention is given to providing a thorough understanding of nutrient recycling and energy flow (Chapter 2), but this is done without resorting to the "heavy" chemistry which caused problems for some students using the first edition. However, a presentation of the basic chemistry is still included in an appendix. Likewise, evolution is given a more thorough treatment (Chapter 4). In each of these chapters there is a concluding section, "Implications for Humans," which sets the stage for the more thorough discussion of environmental issues which comes in the following Parts.

Part II *(Chapters 5 to 6)* addresses the issues of human populations and economic development, stressing the importance of quality as opposed to quantity of life. The fact that sound ecological management is increasingly necessary to maintain (much more to improve) the standard of living of growing populations is stressed.

Part III *(Chapters 7 to 8)* describes the all-important resources of soil and water, and shows how the natural processes which maintain these resources are being upset or undercut by various human activities. It emphasizes how prudent water and soil management is central to sustaining all natural ecosystems as well as agricultural systems.

Part IV *(Chapters 9 to 15)* provides a comprehensive understanding of sources, effects, and control procedures for the major kinds of pollutants affecting water and air. Sediments, sewage, excess nutrients (eutrophication), toxic chemicals, important air pollutants including those of indoor air, and acid precipitation are each given full chapter treatments. Then, Chapter 15 provides a discussion regarding weighing the relative costs of pollution control against the risks of not controlling pollution.

Part V *(Chapters 16 to 17)* addresses the self-defeating nature and pollution hazards of traditional chemical pest control procedures, describes various natural control methods potentially available, and stresses the importance of ecological pest management.

Part VI *(Chapters 18 to 24)* addresses mineral, biological, energy, and land resources. Regarding biological resources (Chapter 19), the values of natural biota in providing a genetic bank essential for maintaining agriculture, and in performing the natural services of maintaining air and water quality, as well as scientific, aesthetic, and commercial values, are stressed as reasons for requiring their conservation and preservation. Three chapters on energy (21 to 23) provide a comprehensive understanding concerning the enigma of oil supplies, of nuclear power and its pros and cons, and of various solar and other renewable alternatives and conservation. How we choose to use land and associated lifestyles is shown (Chapter 24) to be a basic factor affecting all other resources including air and water.

PEDAGOGICAL AIDS

Organization. Each chapter of the second edition of *Environmental Science: The Way the World Works* is rigorously organized and outlined according to a hierarchy of learning objectives, which facilitates students' gaining a clear, comprehensive understanding of each topic.

Concept Frameworks. Each chapter is preceded by a *Concept Framework* which consists of the outline of the chapter and parallel study questions page-keyed to the text. The concept frameworks may be used as: (1) a convenient preview of the chapter; (2) a learning guide; (3) a reference to quickly locate particular sections; (4) as a summary and review.

Vocabulary Words. New terms appear in boldface type where they are first introduced and defined, and later in italics to emphasize the term's use in context. Then, all such words are entered in the Glossary.

Illustrations and Photographs. Nearly 500 photographs and line drawings, many in four-color, enhance the attractiveness of the text. Moreover, all illustrations have been prepared and photographs selected especially to help convey particular concepts and increase understanding. They are all keyed to specific points in the text.

Appendixes. A list of environmental organizations; the metric system and equivalent English units, energy units and equivalents; and basic chemical concepts are included.

SUPPLEMENTARY MATERIALS

The text is accompanied by a Student Study Guide and an Instructor's Manual with test questions keyed to specific sections of the outline (see Concept Frameworks) for each chapter.

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All my students for continually providing the incentive and the testing ground for this work.

Bernard J. Nebel

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WHAT IS SCIENCE? Why Study Environmental Science?

CONCEPT FRAMEWORK

Outline		Study Questions
I. WHAT IS SCIENCE?	**3**	1. What is meant by *objective understanding?* What is its benefit? Relate science and the aim of scientists to objective understanding.
A. The Scientific Method	**3**	2. State why the scientific method is important and describe steps of the scientific method.
1. Observations and Facts	**3**	3. All scientific information is based on what? What requirements are demanded of scientific observations? What are accepted as scientific facts?
2. Hypotheses and Their Testing	**4**	4. What is a *hypothesis?* How is it tested?
3. Controlled Experiments	**4**	5. What is the purpose of scientific experimentation? What is a *controlled experiment?* Why is it important to have a control? Why is it important to test only one fact at a time?

4. Formulation of Theories	**6**	6. What is a scientific *theory?* Contrast scientific facts with theories. Can theories be tested? How?
5. Principles and Natural Laws	**6**	7. What is a *natural law?* What is the predictive value of natural laws?
B. The Role of Instruments in Science	**6**	8. What are the three main functions of instruments in science?
C. Science and Technology	**7**	9. Contrast *science* and *technology.* Describe how they are mutually supporting.
D. Unresolved Questions and Controversy	**7**	10. Give two reasons for continuing controversy over scientific views.
II. SCIENCE AND VALUE JUDGMENTS	**7**	11. Can science make value judgments? Can science aid in making value judgments? How? Can scientific theories and principles be ignored? What are the consequences?
III. ENVIRONMENTAL SCIENCE AND ITS APPLICATION	**8**	12. Define *ecology.* Define *environmental science.* Describe the importance of understanding and applying environmental science. Why does it depend on more than just scientists?

Acid rain, toxic wastes, air pollution, water pollution, endangered species, shortages of resources, nuclear wastes, energy problems, groundwater depletion and contamination, soil erosion, overpopulation—these are some of the many environmental problems we all face. In modern society we have learned to look to scientists for solutions; but many of these problems are perceived as the direct or indirect result of progress in science and technology. Therefore, is science the "hero" or really the "culprit"? Science is commonly seen as a mysterious maze of complex instruments, experiments, and theories, which fascinate some, alienate others, and confuse many. As students about to begin the study of environmental science, you should understand what science really is, what science can do, and, even more importantly, what it cannot do. Through a better understanding of science in general and environmental science in particular, we can indeed solve our environmental problems and build a more secure future.

WHAT IS SCIENCE?

Solutions to some problems may be found through an empirical or trial-and-error approach. However, an accurate and objective understanding of the problem generally enables more effective problem solving. For example, little headway was made in curing infectious diseases when it was thought that they were caused by evil spirits, sins, God's wrath, or emotional feelings. In contrast, the discovery of bacteria and other microbes and the recognition in the late 1800s of their role in causing disease led to the development of effective defenses and cures now used in modern medicine and public health. Likewise, until recently, we believed that mental illness was "all in the head." Today, the recognition of real chemical imbalances permits more effective treatment of certain illnesses. As we learn more about how cells function, we can expect to find more effective treatments for cancer and other diseases.

In brief, the aim of scientists is to develop an accurate, objective picture of what the world is and how it works in the sense of causes and effects—a picture that is free of the distortions that may result from emotional biases, prejudices, errors, or deception. This picture, so far as it has been developed, is the subject matter of science, generally categorized into such areas as chemistry, physics, and biology.

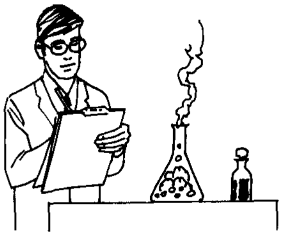
The Scientific Method

Just as important as the subject matter, however, is the **scientific method,** the method of acquiring objective information. How can we be sure that any piece of information is factual? The scientific method begins with observations of things and events, and progresses through the formulation of cause-and-effect relationships called **hypotheses.** In turn, hypotheses are tested by making further observations or through controlled experiments. Finally a theory is developed, which also undergoes testing, and gradually an overall objective understanding emerges. We shall look at each of these steps in more detail.

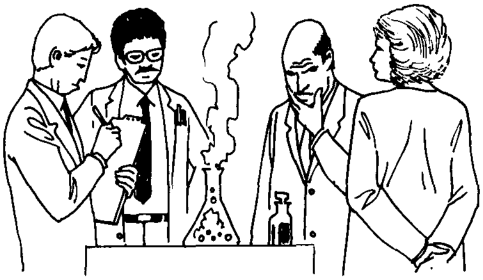
OBSERVATIONS AND FACTS

All scientific information is based on **observations.** However, observations in science are restricted to impressions gained through one or more of the five basic senses in their normal state: that is, seeing, hearing, touching, smelling, and tasting. Only observations made through these senses are accepted because it is felt that only these senses provide us with objective information. For example, contrast your relative confidence in what you see in real life versus what you see in a dream. Indeed, it is well recognized that even with real-life observations there may be distortions due to illusions, errors, or prejudices. Therefore a further demand is made.

All observations must be subject to confirmation and verification. That is, other investigators must be able to repeat the observation, perhaps using different techniques and tests, and confirm, independently, that the original observer is correct. Observations that do not stand the test of confirmation and verification are dismissed. For example, some claim to have seen spaceships with alien creatures, but this information is not generally accepted as factual because such observations have not been repeatable or confirmable. On the other hand, observations that do stand the test of confirmation and verification become accepted as scientific fact (Fig. 0-1).



All Scientific Information Is Based on Careful, Thorough Observations Using the Basic Five Senses.



Further, Observations Must Be Verifiable by Others before They Are Accepted as Factual.

FIGURE 0-1
Scientific observations and facts.

This process of observation leads to a wealth of factual information concerning the physical characteristics of all sorts of things, both living and nonliving. It also gives us a wealth of information concerning how things act: objects heavier than air fall when dropped; water boils and apparently disappears when heated; plants grown on poor soil do not thrive.

HYPOTHESES AND THEIR TESTING

After making an observation, the almost automatic mental response is to find some explanation or cause for the observed event. When the real cause is unknown, the first explanation may be no more than a tentative guess; it is called a *hypothesis*. Of course, the hypothesis may be correct or incorrect. The key point is that hypotheses are tested to see if they are logically consistent with other observations.

A specific thought process used in testing the consistency of a hypothesis is the "*if . . . then . . .*" phrase. One reasons that, if the hypothesis is true, then such and such should logically follow. Finding the "then" to be true provides support for the correctness of the hypothesis. If a hypothesis is inconsistent with other observations it is discarded as false; hypotheses that remain logically consistent with all other observations are gradually accepted as factual. For example, *if* water becomes vapor when heated, *then* we should be able to observe the recondensation of vapor back to water. This is consistent with observations. On the other hand, a hypothesis that water actually vanishes into nothing on boiling is inconsistent with our general observation that things do not just vanish—they go somewhere.

CONTROLLED EXPERIMENTS

Some hypotheses may be tested by making further direct observations, but the testing of others may involve performing experiments. However, the results of experiments may be readily misinterpreted and give rise to capricious information unless they are rigorously **controlled.** Effectively this means that all the factors involved in the experiment are controlled in such a way that the factor being tested provides the only difference between an **experimental** or **test group** and a **control group** that is used for comparison.

To illustrate, the observation that plants do not grow well in some soils gives rise to the hypothesis that plants require certain nutrients from soil. Analysis of soils that support good growth reveals that these soils contain nitrogen, phosphorus, potassium, and other chemicals. We can then ask if these elements are required. Specifically, for example, is nitrogen required? The thought process is, *if* nitrogen is required, *then* plants will not grow in soil lacking nitrogen. The controlled experiment is as follows: investigators develop a nutrient medium in which they can control all of the chemicals. Quartz sand irrigated with a water solution containing the respective amounts of various soluble compounds found in good soil is such a medium. Now, the growth of plants in the complete medium, the *control group*, can be compared with the growth of plants in a medium that is the same in every respect except for the lack of a nitrogen compound. This group of plants is the *experimental* or *test group*. Importantly, all other conditions such as light, temperature, and water must also be the same for the two groups.

A key feature of the controlled experiment is that it must enable a direct comparison between the experimental group, which receives the test treatment, and the control group, in which all fac-