ESSENTIALS OF ENVIRONMENTAL TOXICOLOGY

The Effects of Environmentally Hazardous Substances on Human Health

W. WILLIAM HUGHES
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ESSENTIALS OF ENVIRONMENTAL TOXICOLOGY: The Effects of Environmentally Hazardous Substances on Human Health

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To Asa Thoresen
... a gentle and great man
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The effects of environmentally hazardous substances on human health are an important and timely subject. My goal was to produce an introductory text similar in style to those found in the aged disciplines such as anatomy, biology, botany, and physiology—a text that emphasized the general state of environmental toxicology by concentrating on important principles and avoided the controversies inherent within any discipline (not majoring in the minors).

This text is written for students enrolled in environmental science and environmentally hazardous materials certificate, associate, and baccalaureate degree programs. It has been my experience, having taught environmental science and environmental toxicology during the past 16 years, that these students have diverse backgrounds. The text has been written with an awareness that many of you are just beginning post-high-school studies, some already have advanced degrees, and others are making career changes. It is assumed that the reader has a high-school familiarity with biology and chemistry, but no prior knowledge of environmental toxicology.

*Essentials of Environmental Toxicology* takes a superficial look at what in reality is a very large and complex body of knowledge. Any endeavor to distill a discipline into a few hundred pages of text is laden with an enormous responsibility to avoid misrepresenting data for the sake of simplification—I take full responsibility for any dogma.

Each chapter begins with a list of behavioral objectives and keywords. The keywords appear in bold type and are defined in the text. Chapters are internally organized—introductory principles and examples are given before applications. Figures and tables are designed to illustrate and organize important concepts presented in the text. Each chapter concludes with review questions that may be used by the student for self-testing.

Thanks to Jonna Hughes (mom), my personal and also professional proofreader, whose capacity to use a red pencil is only exceeded by her kindness to family and friends. I am indebted to Kathryn Dowling, PhD, Jon Kindt, REHS, REA, RHSP, and Dennis Woodland, PhD, for providing scientific reviews. Thank you to Dr. Joyce Hopp, Dean, and Dr. Edd Ashley,
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At Taylor & Francis I thank Richard O’Grady, Acquisitions Editor, for believing in the worthiness of my goal, and for providing technical support—especially prompt Internet replies to my queries; Carolyn Ormes, Development Editor, for midcourse corrections in style and deadline reminders; Bonny Gaston, Manufacturing Manager; Catherine Simon and Sharon M. Twigg, Production Editors; and Elizabeth Dugger, Copy Editor.

Asa once remarked that, in his native New Zealand, a man was considered successful if he built a house, had a son, and wrote a book. I built the house; have three wonderful daughters (Stacey, Summer, and Courtney) and a lovely, supportive wife (Marilyn); and wrote the book ... he never told me if two out of three counted! However, my goal is achieved if students who read this book gain an understanding of how toxicants in the environment have their ultimate impact on the health of all organisms in the ecosystem—including our own species.

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Chapter 1

Introduction to Environmental Toxicology

Objectives

- Define environmental toxicology
- Describe the prehistory and history of toxicology
- Distinguish descriptive, mechanistic, and regulatory disciplines of toxicology
- Recognize the multidisciplinary approaches to environmental toxicology
- Summarize the relevance of environmental toxicology to the human species

Keywords

- antidotes
- atmosphere
- biosphere
- cells
- clinical toxicology
- descriptive toxicology
- Ebers papyrus
- ecosystem
- environmental toxicology
- etymology
- forensic toxicology
- hazardous waste
- hydrosphere
- industrial toxicology
- infinite dilution
- lithosphere
- macromolecules
- mechanistic toxicology
- molecules
- morbidity
- mortality
- Orfila
- organ system
- organelles
- organs
- Paracelsus
Keywords (continued)

phytotoxin
poisons
regulatory toxicology
tissue
toxic
toxicants
toxicity
toxins
venom
xenobiotics
What Is Environmental Toxicology?

Environmental toxicology is the study of the poisons around us. A general definition of environmental toxicology would include the hazardous effects that these poisons have on human health. Specifically, “environment” comes from the French word environ, which means “around,” and mens is Latin for “mind.” The word “toxicology” comes from the Greek word toxikon, a poisonous substance into which arrowheads were dipped, and the suffix -logy from the Greek word logos, which means the study of, or treatise.

Some toxicology terms appear to be similar but should be used with specificity to allow for accurate communication. For example, poisons are substances that in relatively small doses act to destroy life or seriously impair cellular function. There are a variety of poisons, many of which occur naturally in plants and animals or as minerals. There are also man-made poisons, which are the direct result of laboratory synthesis. Toxins are poisonous substances produced by plants (phytoxins), animals (zootoxins), or bacteria (bacteriotoxins); a substance is toxic when it acts to destroy or impair cellular function. Toxicity is the state of being poisonous. The term venom refers to poisonous substances secreted by certain animals, such as bees, spiders, and snakes. When substances produce symptoms that are popularly referred to as intoxication (or poisoning) they are referred to as toxicants. There are naturally occurring toxicants, as well as toxicants that result from technological advances involving the manufacture and use of chemicals in industry and agriculture. Xenobiotics (Greek xenos, a stranger; -biotic, pertaining to life) may include substances, such as toxicants, that are not naturally produced within an organism.

Terminology

Learning the vocabulary of environmental toxicology allows for effective and accurate communication. Etymology is the study of word origins. The majority of environmental toxicology terms have their origins in classical Greek (G.) and Latin (L.). In addition to scientific terminology, these “dead” languages are also the source of many common words found in the English language.

Delving into a new discipline, such as environmental toxicology, requires that you learn the vocabulary along with the definitions. A knowledge of how words are formed can substantially reduce the amount of time spent in learning the meaning of new words. In general, scientific terms may contain three parts: a prefix, combining form, and suffix. To define a new term, start on the right and define the suffix, then move to the left, or beginning of the term, and define the prefix or combining form. For example, the word phytotoxin is made up of the combining form phyto, which comes from the G. phytos, a “plant,” and toxin from the G. toxikon, which means “poison”—phytotoxin then is “poison from a plant.”

A good scientific or medical dictionary is an invaluable aid when learning a new discipline. If you take the time to learn the parts of words you will be surprised at your ability to define new
words without having to look them up in a dictionary.

**History of Toxicology**

The prehistoric use of animal venoms (L. venenum, venom) and plant poisons (L. potentio, potion) is evident from archaeological and cultural anthropological studies. Ancient cultures had a working knowledge of many naturally occurring toxins that were used as medicinals, in hunting, and for war. Today, there are indigenous native peoples who still use naturally occurring poisons and toxins for hunting and for medicinal purposes.

One of the oldest written records of the early use of toxins is a series of eight Egyptian papyri dating from 1900–1200 B.C. The Ebers papyrus (Figure 1-1), which dates from 1500 B.C., contains directions for the collection, preparation, and administration of more than 800 medicinal and poisonous recipes. Some have obvious medicinal value, such as the use of opium to alleviate pain. The list also includes names of many potions of dubious medical value. Of interest to

**Beginning of the Book of Medications**

To get rid of the diseases of the body

stir plant with vinegar
to drink by the patient
the same for the stomach, which is ill
Cuminum* (fraction of g)
Geese lard (fraction of g)
Milk (up to 0.6 l)

* Aromatic seeds from *Cuminum cuminum* (family Umbelliferae), a dwarf plant native to Egypt and Syria

**Figure 1-1.** A small portion of the Ebers papyrus. This Egyptian document, written about 1500 B.C., contains the recipes for more than 800 prescriptions. It also describes about 700 drugs of animal, vegetable, and mineral origin. (English translation courtesy of Dr. Gunter Reiss.)
toxicologists are recipes for poisons like hemlock, which was extracted from the dried unripe fruit of the plant *Conium maculatum* (Figure 1-2).

The use of plant and animal toxins by the Greeks was common. Dioscorides (A.D. 50–100), a Greek army physician who served in the court of Nero, the Roman emperor, is responsible for an early attempt to classify poisons. His classification of more than 600 plant, animal, and mineral poisons as being toxic or therapeutic is sufficiently valid to still be used today. The Greeks used

---

**Figure 1-2.** Poisonous hemlock can be extracted from the dried unripe fruit (circled) of *Conium maculatum*. (Original artwork by Lynn Steil.)
poisons as the state method of execution. Socrates, Demosthenes, and Cleopatra were all victims of poisoning, albeit for different reasons, including an execution and two suicides, respectively. Stories exist that the discovery of antidotes, which are agents to neutralize the effects of a poison, was facilitated by giving known toxins to condemned criminals followed by the administration of possible antidotes. When criminals survived these potentially lethal experiments, new antidotes could be added to the list.

The Romans (A.D. 50-400) made use of poisons for executions and assassinations, political or otherwise. By the fourth century A.D. the use of poisons had reached epidemic proportions. Did Agrippina kill Claudius to “clear the way” for Nero to become emperor of Rome? Did Nero subsequently kill Britannicus, Claudius’ natural son, with a soup à la arsenic?

The Islamic empire, following the death of Mohammed in A.D. 632, was strongly influenced by Greek medicine. Avicenna (A.D. 980-1036), a master of many disciplines, was considered to be an Islamic authority on poisons and their antidotes.

Ancient Chinese literature contains abundant references to the medicinal value of numerous plants and the poisonous properties of certain fish. Emperor Shen Nung (ca. 2700 B.C.) is reported to have experimented with poisonous as well as medicinal plants. Indeed, a “cure” for stupidity involved the use of poisons from newts and salamanders.

Hindu medicine in India from 800 B.C. to A.D. 1000 makes references to poisons and antidotes, such as for snake bites. Significant written works on medicine are found in the Ayurveda. Although the Hindus are believed to have borrowed some medicines from the Greeks, there are indications that the Greeks had medicinals of known Hindu origin.

Throughout the Middle Ages, poisons were used to gain political and social, as well as financial, advantage. In Italy, the Borgia family, including Cesare, his half-sister Lucretia, and their father Pope Alexander VI reportedly gained wealth as a result of their timely use of arsenic in wine. The term “lucre” (L. lucrum, gain), originally used to describe riches or wealth, is used now in a humorously derogatory sense. In A.D. 1198, Maimonides, a Spanish rabbi, wrote Poisons and Their Antidotes, which was a first-aid guide to the treatment of poisonings.

In general, the scholarship of the Middle Ages, from the ninth to fifteenth centuries, was based more on dogma than on empirical evidence. The German physician Paracelsus (1493-1541), a product of the Renaissance, brought the study of medicine and science to a new high (Figure 1-3). The role of experimentation, the relationship between dose and therapeutic, as compared with toxic, responses to chemicals, and the specificity with which different doses of chemical agents produce well-defined toxic or therapeutic effects are included in his writings—“What is there that is not a poison? All things are poison and nothing without poison. Solely the dose determines that a thing is not a poison.” These early contributions form the basis of what is now the science of toxicology.

Of particular interest to environmental toxicology are the writings of the Italian physician Ramazzini. Diseases of Workers, published in 1713, deals with ailments that result from exposure to toxic chemicals in the workplace.
The beginnings of toxicology are usually traced to Orfila (1787–1853). With his 1815 book, *A General System of Toxicology, or, A Treatise on Poisons, Drawn from the Mineral, Vegetable, and Animal Kingdoms, Considered as to Their Relations with Physiology, Pathology, and Medical Jurisprudence*, this Spanish physician unknowingly established toxicology as a separate and distinct scientific discipline (Figure 1-4).

**Subdisciplines of Toxicology**

Each day toxicology impacts your life. A trip to your family physician may result in the use of chemical agents to aid in diagnosis, such as contrast agents used to enhance radiographic images. Or you may be prescribed a pharmaceutical agent that will prevent or treat disease. Excessive amounts of these substances can pose a danger to your health. The vegetables you eat may contain chemicals, both those used initially to promote pollination or growth and those added later to prolong shelf life. Animals slaughtered to provide meat may have been treated with chemicals to promote growth. If you check under the kitchen sink or in the garage you probably will find pesticides used to kill insects in the garden or molds growing on the shower tile. Each breath of air you take or glass of water you drink can potentially contain toxicants from a variety of industrial, automotive, agricultural, household, or natural sources.
A GENERAL SYSTEM
OF
TOXICOLOGY,
OR,
A TREATISE ON POISONS,
DRAWN FROM
THE MINERAL, VEGETABLE, AND ANIMAL
 KINGDOMS,
CONSIDERED AS TO THEIR RELATIONS
WITH
PHYSIOLOGY, PATHOLOGY, AND MEDICAL
JURISPRUDENCE.

By M. P. ORFILA, M.D.
OF THE FACULTY OF PARIS, PROFESSOR OF CHEMISTRY AND NATURAL
PHILOSOPHY.

TRANSLATED FROM THE FRENCH.

Unicum signum certum dati veneni est notitia botanica inventi veneni vege-
tabilis, et criterium chemicum dati veneni mineralis.
PLENCK. Toxicologia.

IN TWO PARTS.

London:
PRINTED FOR E. COX AND SON, ST. THOMAS’S-STREET,
BOROUGH.

1816.

Figure 1-4. Title page and a selected Contents page from an 1816 translation of the
Spanish physician Orfila’s 1815 book. (Courtesy of Library of the College of
Physicians of Philadelphia.)
Symptoms of Poisoning by the Nitric Acid:
Observation 1st ........................................... 335
Observation 2nd ........................................... 337
Observation 3rd ........................................... 339
Observation 4th ........................................... 343
Observation 5th ........................................... 345
Application of all that has been said to the different Cases
of Poisoning by Nitric Acid ............................. 352
First Case.—The Patient is dead: the Remainder of the
Poison can be procured ................................ ibid.
Second Case.—The Patient is living: all the Poison has been
swallowed: Matter vomited can be procured ........ 353
Third Case.—The Patient is living: the whole of the Poison
has been swallowed: the Vomitings cannot be procured. 355
Fourth Case.—The Patient is dead ....................... ibid.
Treatment of Poisoning by the Nitric Acid ............ 356
Observation .................................................. 357
Physical Properties of Muriatic Acid ..................... 360
Action of the Muriatic Acid upon the Animal Economy. 363
Symptoms of Poisoning by the Muriatic Acid:
Observation .................................................. 364
Lesions of Texture produced by the Muriatic Acid ... 366
Application of all that has been said to the different Cases of
Poisoning by Muriatic Acid ............................... ibid.
Treatment of Poisoning by the Muriatic Acid .......... 367
Physical and Chemical Properties of the Phosphoric Acid 369
Action of the Phosphoric Acid upon the Animal Economy, 370
Of some other Mineral and Vegetable Acids ............ 370
Of the fluid Nitrous Acid ................................ ibid.
Of the fluoric Acid ........................................ 371
Of the Sulphurous Acid ................................... 372
Of the Phosphoreous Acid ................................. 373
Of the Oxalic Acid ........................................ ibid.
Of the Tartaric Acid ..................................... 374

Figure 1-4. (continued)

Modern toxicology is composed of three subdisciplines. The first, descriptive toxicology, involves toxicity testing of chemicals. Initially, the determination as to whether or not a chemical is toxic must be made before safety and regulatory issues can be addressed. Toxicity testing usually takes place using experimental animals. Second, mechanistic toxicology exam-
Modern toxicology is composed of three subdisciplines. The first, descriptive toxicology, involves toxicity testing of chemicals. Initially, the determination as to whether or not a chemical is toxic must be made before safety and regulatory issues can be addressed. Toxicity testing usually takes place using experimental animals. Second, mechanistic toxicology exam-
ines the biochemical processes by which identified toxicants have an impact on the organism. Although descriptive toxicologists continue to identify agents of toxicity, the exact mechanism by which many toxicants have their action on the organism awaits continued study. Last, regulatory toxicology is concerned with assessing the data from descriptive toxicology and mechanistic toxicology in an attempt to determine the legal uses of specific chemicals, as well as the risk posed to the ecosystem by the marketing of those chemicals.

Many disciplines contribute to an understanding of toxicology (Table 1-1). Of particular interest, clinical toxicology examines the effects of toxicants on individuals and the efficacy of treatment for symptoms related to intoxication. Forensic toxicology is concerned with the medical and legal questions relating to the harmful effects of known or suspected toxicants, and industrial (or occupational) toxicology studies the disorders found in individuals who have been exposed to harmful materials in their place of work.

The scope of this book is environmental toxicology, which deals with the impact of known or suspected toxicants on the ecosystem, including the human population . . . the health hazards posed by the poisons around us. Although this text focuses on the effects of toxicants on the human species, remember that our ecosystem is complex, and potentially all forms of life, both plant and animal, may be affected by toxic substances.

### Ecological Concepts

The biosphere is that region of our planet that contains living organisms (Figure 1-5). Although planet Earth is

| Table 1-1. Selected disciplines that contribute to a more complete understanding of toxicology |
|-----------------------------------------------|-------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Ecotoxicology                                 | Industrial toxicology               | Risk assessment                               |
| Forensic toxicology                           | Environmental toxicology             | Eductional toxicology                          |
| Genetic toxicology                            | Biochemical toxicology               | Immunotoxicology                              |
| Teratology                                    |                                    | Food toxicology                               |
| Cancer research                               |                                    | Clinical toxicology                            |
| Pesticide toxicology                          |                                    | Vasculotoxicology                             |
| Analytical toxicology                         |                                    | Pulmonotoxicology                             |
| Veterinary toxicology                         |                                    | Industrial hygiene                            |
| Hepatotoxicology                              |                                    | Epidemiology                                  |
| Pharmacology                                  |                                    | Medicine                                      |
| Biochemistry                                  |                                    | Atmospheric sciences                          |
| Pathology                                     |                                    | Ecology                                       |
| Environmental law                             |                                    | Genetics                                      |
| Marine biology                                |                                    | Molecular biology                             |
| Soil sciences                                 |                                    | Physiology                                    |
| Cytology                                      |                                    |                                              |
Figure 1-5. The biosphere includes those regions of the atmosphere, hydrosphere, and lithosphere where living organisms are found.

Quite large, the region where life can be found is just a thin veneer on the earth's surface, usually involving only a few meters of the lithosphere and a few kilometers of the atmosphere and hydrosphere. The ecosystem is a self-regulating community of animals and plants interacting with one another (biotic interactions) and with their non-living environment (abiotic interactions). Our ecosystem does not exist in a vacuum. Every activity, process, and interaction influences the ecosystem—much like the ripples that result when a stone is thrown into a pond go out and disturb the pond. When biotic or abiotic factors in the ecosystem are disturbed, they in turn will influence the interacting populations to either grow or decline in their numbers. These are often referred to as positive or negative feedback mechanisms, respectively.

Since time is a fundamental variable to everything that happens in an ecosys-
the time-dependent rates for changes to biotic and abiotic interactions in the ecosystem are important questions to consider—how fast the “ripples” travel. Our concept of time affects the questions we ask and the solutions we propose. A very short time may involve the instantaneous changes that last less than seconds, such as when lightning discharges or chemical reactions take place. Human time is usually the span of time in which most of us think, and it is in this unit of time that we make most of our observations about the ecosystem. “Long-term” planning within the constraints of the human time frame rarely exceeds 20 years. Historical time involves intervals of time that are too long to be studied by individuals. It is dependent on records provided by earlier generations. Geological time refers to long-term changes within the ecosystem. Within this time frame the processes that shape our earth and influence the structure of the ecosystem are measured. The drifting of continents, mountain building, and geological cycles of erosion and deposition of sediments are all processes that require long periods of time. Then there is deep time or stellar time—the time in which the universe exists, stars begin and end, and planets are formed.

Not surprisingly, our “long-term” planning is at odds with the stability of our ecosystem. The changes we precipitate are occurring at rates that are too fast, too overwhelming, for an ecosystem shaped over millions of years. The fact that environmental toxicology has developed into a significant discipline indicates that we have exceeded the self-regulatory ability of our ecosystem. To evaluate the profound impact we have made on the environment, including the relevance of environmental toxicology to our survival as a species, requires an understanding of (1) the sources of toxicants, (2) environmental cycles that transport toxicants, (3) the modes by which these toxicants enter and affect the human body, and ultimately (4) the degree to which society defines safety and what risks are acceptable as related to our exposure to toxicants.

Relevance of Environmental Toxicology to the Human Species

The human species has had a significant impact on the ecosystem. Apparently, early humans were better able to coexist with other animal and plant populations, most likely due to their small population size and reduced demands on the ecosystem. However, with the recent rapid increase in the size of the human population (including advances in industry and transportation, and economies based on continued growth) our once benign interaction with the ecosystem has changed into one where the demand for resources, such as food, water, and habitable space, is exceeding the supply.

An end product of the consumption of these resources is a tremendous amount of waste. For many decades infinite dilution was a common solution to the problem of waste disposal. Vast oceans (hydrosphere), land (lithosphere), and air (atmosphere) (Figure 1-5) were the “buckets” in which “drops” of potentially toxic wastes were diluted—indeed, waste disposal was viewed as just that—a “drop in the bucket.” It was further thought that the
toxic wastes would be of no consequence or harm to human health since the “buckets” were so vast. Somehow we forgot that eventually we would be exposed to the cumulative effect of the “drops” of toxic substances as we eat, breathe, and sleep in the “buckets.”

Hazardous waste is defined as waste that, because of its biological, chemical, or physical characteristics, or quantity or concentration, may pose a danger of morbidity (disease) and mortality (death) to organisms (Figure 1-6). To illustrate the magnitude of the problem, in the United States alone over 4 billion tons of waste is generated each year from mining, agriculture, industry, and city sewage sources. On an average, each person contributes over 4 pounds of domestic solid waste each day. Of the approximate 274 million metric tons (1 metric ton = 2,200 lb) of this waste, which is subject to regulation as hazardous waste by the Environmental Protection Agency (EPA), only an estimated 10% is disposed of in an environmentally safe manner.

With over 5 million natural and man-made chemicals and over 80,000 synthetic chemicals currently being used in industry, agriculture, household, and other applications, the potential for exposure to hazardous waste is a concern. The health hazards for individuals who are exposed to hazardous wastes, as well as other toxic substances, when they are disposed of in an unsafe manner, poses a serious problem. This is especially true when cause-and-effect relationships are established between certain wastes and diseases. For example, based on worldwide epidemiological data the World Health Organization (WHO) estimates that 90–95% of all cancers are “environmentally related”—an environment we have disturbed is now afflicting our own population with morbidity and mortality.

Although contact with toxic substances may come as a result of occupational, accidental, or intentional exposure, there are some contacts or exposures over which we have little or no control. The saying that you can run but you can’t hide is certainly true for aspects of the atmosphere, hydrosphere, and lithosphere on which we are dependent for our survival. We may unknowingly breathe air, drink water, or eat food that was polluted with toxicants hundreds or thousands of miles away.

The data of environmental toxicology should prompt us to stop or limit the sources of those substances that threaten to harm plant and animal species in the ecosystem. As a result of descriptive, mechanistic, and regulatory toxicological study, we will be better able to provide for the future of our species. It is with an awareness of these factors that environmental toxicology has its relevance to the human population.

**Structural Levels of Organization**

Nature can be organized into different levels of structural complexity, from subatomic particles to the ecosphere (Figure 1-7). Carbon (C), hydrogen (H), oxygen (O), nitrogen (N), calcium (Ca), potassium (K), and sodium (Na) are a few of the atoms essential to living organisms. When two or more atoms join together, molecules are formed. The molecules may be small (e.g., amino acids, simple sugars) or they may combine to form larger molecules called macromolecules, such as proteins. Cells are composed of complex
Figure 1-6. From waste to disease. The paths by which wastes, including toxicants, move into the biosphere where they produce morbidity. (From C. E. Kupchella and M. C. Hyland, *Environmental Science*. Allyn and Bacon, 1989. Reprinted by permission.)
assemblages of atoms, molecules, and complex molecules.

Cells are the basic unit of structure and function in a living organism. All of the functional or physiological processes in organisms ultimately take place at the level of the cell. Within the cell are small structures called organelles that carry on specific activities.

Cells may be organized into units that together perform a similar function. These assemblages of cells are termed a tissue. There are four distinct tissue types in the human body: epithelial tis-
sue, which covers the body and lines ducts and vessels; connective (or support) tissue, such as blood, bone, and collagen; muscle tissue, with smooth, skeletal, and cardiac types; and nerve tissue, which includes neurons.

**Organs** result when groups of different tissues unite to form structures that perform a specific function. Two or more organs may combine to form an **organ system**. For example, the use of food resources by the human body is accomplished by numerous organs (the gastrointestinal system), each of which functions in sequence to permit ingestion (e.g., oral cavity), mechanical and chemical digestion (e.g., stomach), absorption of nutrients (e.g., intestines), and elimination (e.g., anus).

Toxicants produce toxic effects by interacting with the molecules on or near the surface of, or within, the cell. The interactions in turn cause reversible or irreversible cellular damage by affecting proteins associated with the cell membrane (e.g., receptors), interfering with a cell’s energy production (e.g., metabolism), binding to molecules within the cell (e.g., enzymes), or causing certain cells to die. Although environmental toxicologists may observe the gross effects of a toxicant on the whole organism, remember that the cumulative effect of the **disruption of structure and function at the level of the cell** is ultimately responsible for organismal morbidity and mortality.

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**Review Questions**

1. A general definition of this term would include a study of the hazardous effects that the poisons around us have on human health:

   A. Descriptive toxicology  
   B. Environmental toxicology  
   C. Forensic toxicology  
   D. Mechanistic toxicology  
   E. Regulatory toxicology

2. Which term has its origin in the Greek word for “stranger”?

   A. Poison  
   B. Toxin  
   C. Toxicant  
   D. Venom  
   E. Xenobiotic

3. This Greek physician served in the Roman emperor Nero’s court and is responsible for classifying more than 600 plant, animal, and mineral poisons as being toxic or therapeutic.

   A. Avicenna  
   B. Dioscorides
C. Maimonides
D. Ramazzini
E. Shen Nung

4. Identify the source of this statement: “All things are poison and nothing without poison. Solely the dose determines that a thing is not a poison.”

A. The Ayurveda
B. The Ebers papyrus
C. Maimonides
D. Orfila
E. Paracelsus

5. Which area of toxicology is concerned with assessing the risk involved in the marketing of chemicals and their legal uses?

A. Descriptive toxicology
B. Forensic toxicology
C. Industrial toxicology
D. Mechanistic toxicology
E. Regulatory toxicology

6. “Long-term” planning within the constraints of the human time frame rarely exceeds 20 years.

A. True
B. False

7. It is estimated that 10% of hazardous wastes are disposed of in an environmentally safe manner.

A. True
B. False

8. In the human body, physiological processes ultimately take place at which level?

A. Cell
B. Tissue
C. Organ
D. Organ system
E. Organism

9. List five disciplines that contribute to a more complete understanding of toxicology.

10. Construct a diagram that shows the relationship between hazardous wastes, and morbidity and mortality.