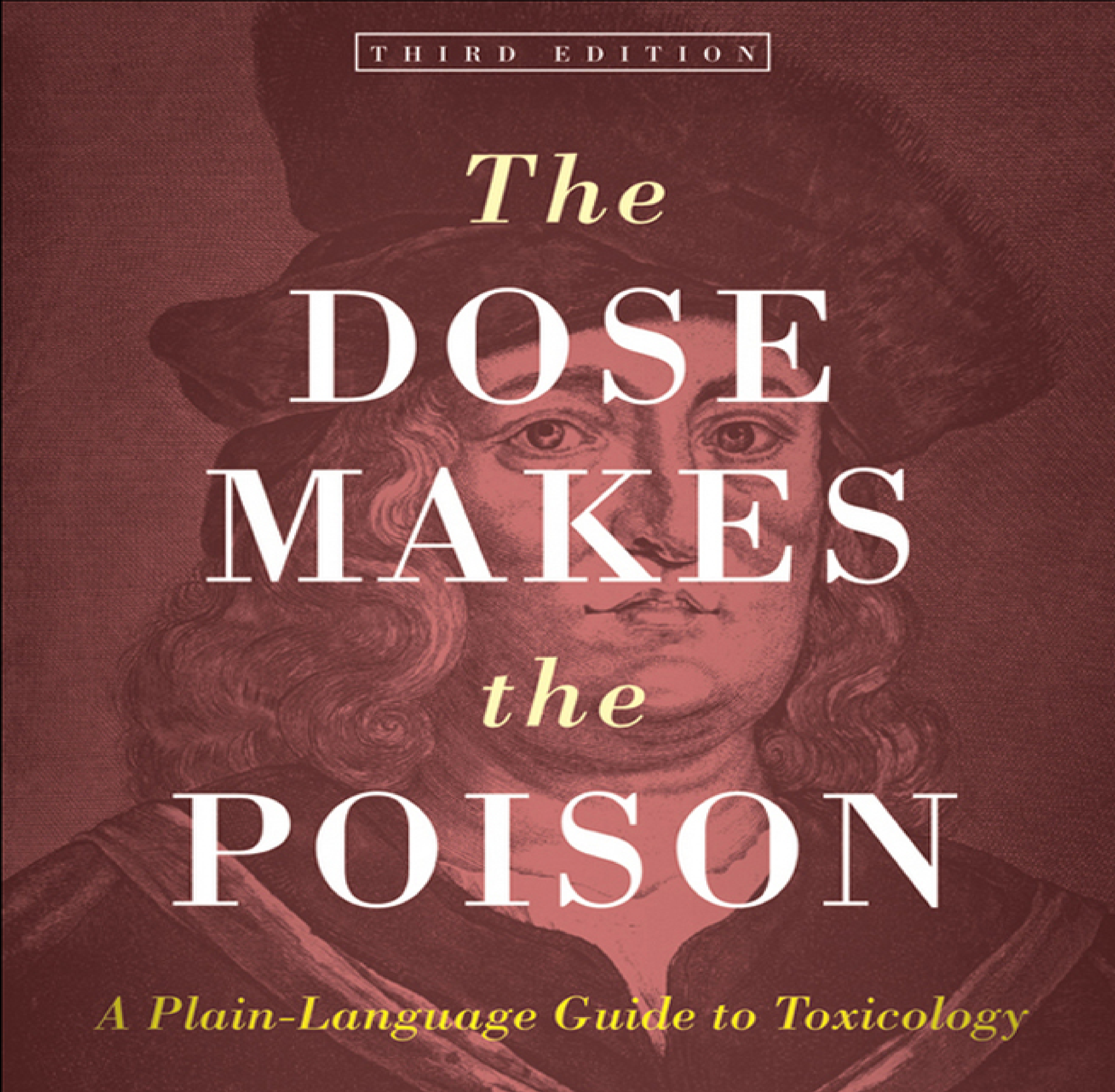

THIRD EDITION

The DOSE MAKES *the* POISON

A Plain-Language Guide to Toxicology

PATRICIA FRANK
M. ALICE OTTOBONI

WILEY

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M. ALICE OTTOBONI, PH.D.

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INTRODUCTION TO THE THIRD EDITION

When I was asked to revise this book for the third edition, I wanted to increase its scope from dealing primarily with environmental chemicals to dealing with all types of chemicals that we confront every day, not only environmental chemicals, but also drugs, food additives, vitamins, and others. I have included most of the preface and introduction to the second edition so that you can see Alice Ottoboni's original intention and also her insights into toxicology that were presented there.

I think that broadening the scope is important because each day I read several newspapers, newsmagazines, the Internet news, various blogs, and so on, and each day I see articles about all the "poisons" in our world. Some of the articles point out which pesticides are found as residues on peaches, how much lead is in Barbie's shoes, what drugs are found in our drinking water, and other facts or nonfacts. Other articles have a viewpoint to share and it seems their raison d'être is to scare the public. As I read them, I can imagine how disturbed a nontoxicologist would be to see all the headlines and not know what to do about these frightening things. The days are long over when we can be comfortable that our food supply, our water supply, our drugs, vitamins, and cosmetics are as safe as we would like. So it is important to increase our understanding of all types of chemicals in our ever more complex world.

Our society has made great strides in controlling the unbridled spread of various chemicals into the environment. From the removal of arsenic from cosmetics and drugs in the early 1900s, the establishment of the Environmental Protection Agency in 1970 in order to control the use of pesticides and set standards for air and water quality, up to the empowerment of a modern Food and Drug Agency that monitors our medicines and medical devices, we have taken steps to ensure the safety of many products.

Some of us were lulled into complacency that the world was becoming a safer place. That balloon burst in the 1980s when there were some terrible industrial accidents such as at a Bhopal, India, factory as well as consumer product tampering, all of which led to sickness and deaths of innocent bystanders. Today, with the advent of serious industrialization of nonwestern economies such as China and India, the integrity of our food supply is once again in question and the safety of various consumer products and medicines may be at risk.

Lest we be lulled into a sense of complacency over environmental safety, toxic waste spills still occur with serious impact on both humans and wildlife. For example, two of the headlines in 2009 concerned an ammonia leak that killed someone who drove into the gas cloud and the hospitalization of a worker exposed to a large spill of aniline. As I am finishing this book, I am watching with horror the beginnings of what may be the worst oil spill in U.S. history, namely the sinking of an offshore oil rig in the Gulf of Mexico and the consequences to our environment and economy from millions of gallons of oil washing ashore along the coastal states. The long-term consequences of wildlife and human exposure to the inhalation of oil fumes and the ingestion of oil residues in our food and water are certain to be discussed for the next decades. This is all the more reason for the public to understand how to assess risk in order to determine when to be curious, when to be nervous, and when to be truly scared.

Because I have spent most of my career working in the area of pharmaceutical development, many friends ask me questions about their medications. My response always starts with “What did your doctor say?” And the answer is usually either “I didn’t ask” or “He/she didn’t know.” Most people are surprised to find that there are side effects from drugs. I tell them that *all* chemicals have side effects. It is only where on the scale of toxicity a chemical falls. My very simple, on-a-cocktail-napkin scale is:

|--|

Water Cyanide

So where does your medicine, food, water, pesticide fall on this scale?

I hope by the end of this book that you will be able to use the information presented in order to be a more informed consumer of food, water, and medicinal products and to be able to establish your own risk-benefit scenarios for many aspects of your life. In the last chapter of the book we take an in-depth look at how to assess risk while in Chapter 8 we present a variety of case histories that explicate some of the issues surrounding the use of chemicals in our industrial society. Some of these examples are a bit old, but they still have relevance as cautionary tales.

As always with an undertaking such as this, there are many people to thank. First, Alice Ottoboni, whose first two editions laid all the groundwork for this edition, has been a great source of help and encouragement. I also appreciate the input of our editor, Jonathan Rose, and his staff and the critical eye of Barbara Flynn-Waller. Of course, I am grateful to my husband, Jerry, for his thoughtful comments and consistent encouragement, not only for this book but during my whole career.

PATRICIA FRANK, 2010

PREFACE TO THE SECOND EDITION

The natural laws that direct the orderliness of our world are part of our everyday lives. People know that water always runs downhill, that apples always fall to the ground when their stems break, and that the sun always traverses the sky from east to west. Natural laws are immutable, constant, and predictable. So it is with the laws that govern the behavior of chemicals, natural or synthetic. The toxic effects of a given chemical depend on dose (how much), frequency of exposure (how often), and the route by which the chemical enters the body. It always has been thus, and there is no reason to believe it will ever be otherwise. Yet some people find it difficult to believe that chemicals follow any rules at all.

The laws that govern the toxicity of chemicals do not readily manifest themselves in our daily routines, with the result that we have little knowledge or awareness of them. Thus, at the end of World War II, when the rapidly developing petrochemical industry presented us with a host of new synthetic chemicals, whose names we could not pronounce and with which we were unfamiliar, a certain segment of our population became suspicious; anything man-made was viewed with mistrust. Then, in the early 1960s, when the public media began its intense and continuing focus on private worries and concerns that synthetic chemicals were causing great damage to wildlife, the environment, and even us humans, many people became frightened.

Fear of many synthetic chemicals has not abated, despite a lack of objective evidence that they have been detrimental to the public health. Americans are living longer and are healthier than ever before in our history. Nevertheless, a significant segment of our population still believes that many synthetic chemicals are harming them and threatening them with cancer. Adults who remain resistant to chemophobic fears for their own health are challenged to come into the fold with stories of dire consequences for their children. Recently, claims of immune system damage and loss of reproductive capability from exposure to synthetic chemicals have added to the burden of fear.

This book was written with a firm conviction that fear of certain chemicals, or more specifically fear of certain synthetic chemicals, is the product of a lack of understanding of the naturals laws that govern toxicity and, as a corollary, a conviction that knowledge of what makes a chemical harmful or harmless can help dispel unreasoning fear and aid in our dealing more effectively with some of the real problems related to chemical exposures.

I have found, from my many years of working for and with the public, that most people are intelligent and perceptive individuals who want scientific facts relating to subjects that are vital to their health and well-being. Even without scientific education, they are completely capable of understanding such facts. This book is for them. Its purpose is to provide facts about the toxicity of chemicals and to help people to cope with news and media reporting, preserve their sanity in the face of poison paranoia, and make informed judgments about chemicals in the environment.

The public's fear of chemicals, combined with increasing recognition within government and industry that people must be protected from harmful exposures to chemicals, has resulted in a dramatic increase during past decades in the number of laws regulating environmental chemicals. There has been little substantive change in these laws, outlined in the section "Regulation of Toxic Chemicals," since the publication of the first edition of this book.

Through the years, there have been numerous challenges to the Delaney Clause, with groups fearful of human exposures to synthetic chemicals lobbying to expand its coverage, and groups concerned that the Delaney Clause excludes scientific judgment in its implementation lobbying to eliminate it. The matter was put to rest for the time being with the passage, in August 1996, of the Food Quality Protection Act, which supplants the Delaney Clause. This change, while of significance to the lobbyists, both for and against the Delaney Clause, will probably have little or no impact on public health. However, the debate has begun anew about the benefits and detriments of the change.

I am grateful to the many friends and associates with whom I have discussed this second edition for their very valuable comments and criticisms. I owe a special debt of gratitude to my husband, Fred. His sharing of his knowledge of public, occupational, and environmental health has been of tremendous benefit to me not only in the preparation of this second edition but in all of my professional activities.

INTRODUCTION TO THE SECOND EDITION

Many years of service as a public health toxicologist for the California Department of Public Health (now the Department of Health Services) made it disturbingly clear to me that an inordinate fear of chemicals was the rule rather than the exception among the general public. During the same years, participation in training programs designed to teach people how to work safely with the chemicals they contacted in their occupations taught me that people with no science background were not only capable of understanding the basic principles of toxicology but that they could also apply what they learned to work safely and comfortably with some very dangerous chemicals. This book was born of these two observations.

There is a general lack of public understanding about what makes chemicals toxic, and about the word that has become a synonym for *toxic*. That word, now a part of our everyday vocabulary, is *poison*. Headlines tell us about the poisons in our food, poisons in our water, poisons in our air; poisons everywhere! People who use the word most freely appear to have the least concept of what poison means. The indiscriminate use of the word has brought us into an era of what might be termed *poison paranoia*.

Whenever some misfortune occurs for which we have no ready explanation—an illness, a mischance of nature, a declining wildlife species—we look to blame some chemical. This propensity is aptly illustrated by the mystery of the double-yolked eggs, reported in the Consumers Cooperative of Berkeley newspaper, the *Co-op News*, July 16, 1979: "Science is beautiful, but it can sometimes spoil a good news story." The story went on to tell that a Co-op member was recently amazed when she found NINE double eggs out of a dozen box. I shared her astonishment, convinced that either the odds against this marvelous happening were billions to one or that some horrible chemical additive fed to a chicken had caused it and that some serious muckraking was needed down at the chicken ranch to protect embattled consumers by eliminating this poison from their diet.

The Co-op home economist checked with the supplier of the eggs and received a reply that took all of the mystery out of the event by placing it squarely in the dull world of young chickens and egg sorting, where neither chemicals nor miraculous odds were at issue.

Young chickens are apt to pop more eggs with two yolks, but it becomes more uncommon as they reach maturity. The reason nine eggs could wind up in the same box is because double eggs are oversized, so they get set aside by the egg sorter because they won't fit in the egg container. However, there are some borderline ones which the sorter selects from those set aside and allows to pass through. This is why so many were in one box.

Fortunately, in the case of the double-yolked eggs, further facts were sought and the real reason for the apparent anomaly was discovered, thereby avoiding another scare headline. Unfortunately, such dedication in pursuit of truth is often the exception rather than the rule.

There are two diametrically opposed dangers in news media toxicology and its offspring, poison paranoia. One is the cry-wolf syndrome. When an alarm is sounded frequently and without regard to degree of emergency, the alarm becomes meaningless and, therefore, is not effective when a true emergency exists. It is well known that to call everything bad, in effect, is to call nothing bad. If safe and sane use of chemicals in our homes, work, and recreation places is to be furthered, there must be understanding, cooperation, and support on the part of the public. A public blasé about harmful effects of chemicals is a public disinterested in making any changes in use practices relating to chemicals. Such a public attitude would be tragic.

The second danger is that a certain fraction of our population will become victims of a helpless, hopeless fear and terror that chemicals from which they cannot escape—chemicals in their food, their water, their air—are destroying their health, shortening their lives, or dooming them to cancer. Such a fear is a form of stress that can be just as damaging as the chemicals that are feared, and in some cases even more so. Stress can produce vague feelings of illness, such as nausea, headache, weakness, and malaise, as well as actual physical illness. The medical profession now generally accepts the premise that stress can exert a profound influence on the course of many illnesses and appears to trigger or worsen some diseases, such as high blood pressure and Crohn’s disease (a type of colitis).

Poison paranoia already is taking a toll in the mental health and well-being of some people. This conclusion is based on the many thousands of calls, letters, and visits that I have received from people concerned about the health effects of chemicals in their environments. The gamut of their concern extended from calm interest to outright panic. In a few cases, the cause for apprehension was valid because, through some accident, misuse, or lack of knowledge, there had been an actual or potential exposure to a harmful level of some chemical. However, in the majority of cases, the fears or concerns were ill-defined and prompted, in the main, by the most recent scare headline. Among the latter, there were a few people who refused to accept any information that did not support their conviction that they were suffering from some sort of chemical poisoning. People who fall victim to an unreasonable fear of chemicals are literally frightened sick. Frightened people truly suffer. They are victims of distorted information and lack of knowledge.

The great majority of people are seriously concerned about the many chemicals reported to be harming them and the environment, but they do not have a pathologic fear about the effects of chemicals on their health. For the most part, they do not know what to do about the situation, other than to modify their lifestyles to the extent possible. They can live without smoking, but they cannot live without breathing.

This book is not intended as a condemnation of, or an apology for, synthetic chemicals; rather its aim is to present an objective discussion of what makes chemicals harmful or harmless. I feel compelled to make this point so that the reader will understand that I hold no brief for or against synthetic chemicals; they are facts of life with which we must deal. I have learned from many years of contact with people of all viewpoints regarding the risks posed by chemicals that objectivity often invites scorn from both extremes of view. Thus, both pro- and anti-chemical extremists may take exception to all or parts of this book because it is not directed toward reinforcement of their respective “what’s-the-fuss” and “ain’t-it-awful” views. This book is not written for people of extreme persuasions but rather for people who want a real understanding of the significance of their many chemical exposures. Only people with open minds are tolerant of concepts that are new to them or in conflict with their beliefs.

The comfort provided by knowledge was vividly brought home to me many years ago by a young woman who called for information about a chemical. After a rather lengthy conversation, she said, “I feel so sorry for you. You know so much about all the harmful effects of the chemicals that surround us that you must really worry all the time.”

I was surprised by her statement, because such a thought had never occurred to me. I assured her that, on the contrary, the very fact that I do know what makes chemicals harmful frees me from worry. All chemicals follow the same rules: the laws of nature. By knowing the rules, I have a perspective that protects me from needless worry and unreasoning fear. My hope is that this book will give you the same perspective.

M. ALICE OTTOBONI, 1997

CHAPTER 1

WHAT ARE CHEMICALS?

The word *chemical* has become a dirty word in our modern American vocabulary. Our public media provide us daily with advice or warnings about the presence of chemicals in our food, air, and water and the harm they are doing to us and the world we live in. As a result, the word *chemical* conjures up visions of damage, debility, disease, and death in the minds of many people. In order to understand the threats posed by chemicals—a prerequisite to wisely protecting ourselves and our environment from their adverse effects—we must clarify or reform our concept of *chemical*.

ATOMS AND MOLECULES

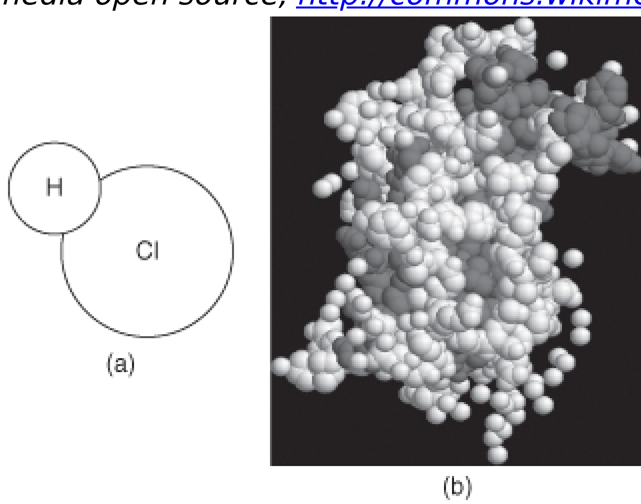
All matter is composed of chemical elements. An individual unit of an element is called an atom. Atoms are the basic building blocks for all substances. Approximately 90 different kinds of stable elements are found in nature. Examples of elements are hydrogen, oxygen, carbon, nitrogen, gold, and silver. A complete listing of all of the elements, including those that are unstable (radioactive), can be found in any good dictionary. The periodic table gives detailed information about all the elements and the relationships among them. A multicolored diagram of the periodic table and an explanation of how this table is constructed can be found at the Los Alamos National Laboratory Web site (http://periodic.lanl.gov) or the University of Sheffield Web site (www.webelements.com).

Appendix A describes the concept of Avogadro's number and molecular weights for those who might be interested.

When two or more atoms (usually of different elements) are linked together by chemical bonding, they form units called molecules. A substance composed of molecules all of the same kind is called a compound. Water, salt, and sugar are examples of compounds. The number of different kinds of molecules that can be formed by the combination of from two to many thousands of atoms, from more than 90 different elements, is astronomical. Figure 1-1 shows the structures of a very simple and a very complex molecule. All substances are composed of chemical and physical combinations of atoms (elements) and molecules (compounds). Thus, everything in our physical world is chemical—the food we eat, the water we drink, the clothes we wear, the medicines we take, the cosmetics we use, the plants in our garden, our furniture, our homes, our automobiles, and even ourselves. Our entire physical world is composed of chemicals.

FIGURE 1-1 (a) Hydrochloric acid, a simple compound; (b) growth hormone, a complex compound.

[Part (b) from Wikimedia open source, http://commons.wikimedia.org.]



NATURAL CHEMICALS

The total number of chemical compounds in our universe that occur naturally will never be known exactly, but, from the millions that have been identified thus far, we know that the total number is huge. Natural chemicals may be organic (i.e., containing carbon) or inorganic. Our inanimate world is an inorganic world. It is composed of a great number of mineral substances in which all of the elements, except for a few radioactive elements that have been created by nuclear scientists, are represented.

Our living world is composed primarily of organic compounds, the diversity of which is tremendously greater than that in our inorganic world. The number of natural organic compounds that has been identified thus far, although very large, is probably negligible compared to the number of those yet unidentified. Many of these as-yet-unidentified organic chemicals—components of the trees, shrubs, and other plants of the rain forests—could well be of great value to medical and pharmaceutical sciences.

One small segment of our organic world, food plants and animals, provide us with the nutrients that we use to build and repair our bodies. However, the plants and animals we use for food contain many more natural chemicals than just the nutrients we require. Since it is impossible to separate nutrients from non-nutrients in our foods, we depend on our bodies to do this work for us. There are many kinds and quantities of nonnutrients in our foods, particularly our plant foods. The animals we use for food have already done the job for us of selecting nutrients and eliminating most of the nonnutrients from plants.

Among the natural chemicals that we eat, many can cause adverse effects if consumed in excess. In fact, there is probably no food that does not contain some potentially harmful natural chemical. This fact is the basis for an annual project of the American Council on Science and Health (ACSH).[*] Every fall the ACSH publishes a typical

Thanksgiving menu accompanied by identification of the naturally occurring toxic or carcinogenic chemicals present in each food on it (found at www.acsh.org). For example, taken from the 2009 menu are heterocyclic amines, acrylamide, benzo(a)pyrene, ethyl carbamate, dihydrazines, d-limonene, safrole, and quercetin glycosides—and this just from the turkey with stuffing! If you are keeping to a vegetarian diet, then the 2009 menu shows salad may contain aniline, caffeic acid, benzaldehyde, hydrogen peroxide, quercetin glycosides, and psoralens.

An interesting method for ranking the potential health effects from exposure to such toxicants that occur naturally in foods was developed by Bruce Ames and his colleagues at the University of California, Berkeley. Dr. Ames has written numerous articles for both scientific and popular publications reviewing the subject of naturally occurring toxicants and their carcinogenic hazards. Rankings are based on data from the scientific literature as well as from Dr. Ames's own laboratory, using accepted methods of risk assessment. These rankings are one approach to the evaluation of relative health risks posed by suspected carcinogens, both natural and synthetic.

SYNTHETIC CHEMICALS

Humans, in their ingenuity, have been able to take the basic building blocks of which all matter is composed and link them together in new combinations to produce compounds not found in nature. Thus, we have a host of synthetic substances, primarily organic, available to us, which we put to a seemingly endless variety of uses—pharmaceuticals, pesticides, and polymers of all sorts, including the common household plastics with which we are so familiar.

The term *organic* has been extensively used by the health-food industry to mean one thing and used by chemists to mean another; as a result, the term is generally misunderstood by the public. *Organic* has come to mean something (usually food) that is naturally occurring or produced without the use of pesticides or other synthetic chemicals, such as hormones. Scientifically, organic chemicals are simply chemicals composed primarily of the element carbon, independent of whether they are natural or synthetic. It comes as a shock to many people that almost all synthetic chemicals, including pesticides, are organic chemicals. The term *organic* was coined long before the birth of modern chemistry.

Early scientists who studied the composition of matter recognized that substances produced by living organisms were different from all other chemicals then known to humans. They called the former *organic* (derived from organisms) as opposed to the latter, which they classified as *inorganic*. Early in the nineteenth century, scientists discovered that the element carbon was present in all organic compounds; hence carbon chemistry became synonymous with organic chemistry.

The great complexity of carbon chemistry, relative to inorganic chemistry, the large size and complicated structures of many organic compounds, their great number and variety, combined with the fact that organic chemicals were found only in living organisms or products of living organisms led the early-day chemists to endow organic chemicals with mystical properties. They considered that the laws that governed the behavior of inorganic chemicals did not apply to organic chemicals; humans could synthesize—that is, manufacture—compounds such as nitrous oxide and hydrochloric acid but were incapable of synthesizing organic compounds in the laboratory at that time.

The special properties of organic chemicals were attributed to the action of a supernatural force, the “vital force," as distinct from the crude and vulgar forces that governed inorganic chemicals. Jöns Berzelius, a noted chemist of the early nineteenth century, wrote that the vital force was unrelated to inorganic elements and determined none of their characteristic properties. Berzelius considered that the vital force was a mysterious property beyond comprehension.

The birth of synthetic organic chemistry occurred at about the time of Berzelius's writing, with the first laboratory synthesis of an organic chemical, using basic chemicals as starting materials. The first synthetic organic chemical was oxalic acid, made by the German chemist Friedrich Wohler. A short time later in 1824, Wohler also synthesized urea. After this accomplishment, Wohler wrote to Berzelius to tell him that he had prepared urea, a chemical found in the urine of animals, "without requiring a kidney or animal, either man or dog."

The notion that organic and inorganic chemicals were qualitatively different persisted for decades after the revolutionary demonstration that humans could, indeed, synthesize organic chemicals. The science of chemistry was greatly retarded until the chemical properties of carbon and its place in the periodic table were more fully understood. The great numbers of synthetic organic chemicals that have been created since the end of World War II were not of much public interest until the publication of Rachel Carson's book *Silent Spring* in 1962. This book stimulated great interest in the effects of pesticides on environmental and public health and brought to public attention the proliferation of chemicals.

The number and variety of synthetic organic chemicals are truly amazing. In 1978, the American Chemical Society's registry of chemicals listed over 4 million organic and inorganic chemicals; of this number, more than 95 percent were organic. Of all the known organic chemicals, perhaps half are naturally occurring chemicals that have been synthesized in the laboratory or isolated from natural sources. Between 1965 and 1983, 6 million additional chemicals had been produced, and the rate of synthesis has only increased since then.

For the average person, what is the significance of the existence of these millions of chemicals? Among those that are not naturally occurring, a great many exist only in small quantities in vials on chemists' benches or in chemical storerooms. They have not been found to have any practical use or function, and so they have not been developed commercially—yet. However, with the advent of high-throughput screening techniques where robotics speed up the screening process, many thousands of chemicals can be rapidly analyzed for their ability to bind to various animal and human chemical receptors. Out of this screening, chemicals that were once thought to have no value are being identified as potential medicines and pesticides and for other human uses.

The toxicity of synthetic chemicals—that is, the degree to which they are poisonous—covers the entire range from essentially nontoxic to extremely toxic. This is also true of inorganic compounds (think water and arsenic). Some synthetic chemicals, such as artificial sweeteners, are edible, whereas others, such as chemical warfare agents, are lethal in extremely small amounts. Regardless of the degree of toxicity, the principles of toxicology apply equally to all chemicals, whether synthetic or natural, organic or inorganic.

The number of chemicals that actually enter homes is not known, but a survey of the wide variety of products found in the home setting—such as cleansers, polishes, drugs, cosmetics, prepared foods, pesticides and other garden chemicals, automotive products, and hobby products—suggests that it is quite large. Despite the wide variety of products, many contain the same basic chemicals. Thus, the actual number of individual chemicals that the average person comes in contact with in home products is probably much closer to several thousand rather than several million. The majority of chemicals that enter homes are not harmful when used properly, but some are treated with a more cavalier attitude than is warranted, as witnessed by the numerous accidental poisonings that occur in children.

The people in contact with the widest variety of potentially dangerous chemicals are those in businesses or professions that use chemicals in some process or procedure and those who work in industries that synthesize, manufacture, formulate, or use chemicals to make other products. Few of these chemicals find their way into a home setting.

CHEMICAL CATEGORIES

We categorize chemicals in many different ways, the broadest of which is whether they are natural—produced by a living process—or synthetic—made by humans. Other ways we classify chemicals are by the use we make of them (foods, drugs, pesticides, etc.), how they are physically organized (solid, liquid, gas), what kind of animal they are (fish, reptiles, birds, mammals, etc.), whether they are organic or inorganic (animal, vegetable, or mineral), and so forth. Plant and animal probably were two of the earliest categories recognized by humans. Plants stayed put, whereas animals usually moved about freely. Based on this classification, corals were considered plants for many years until their animal nature was discovered.

A scheme of classification by the use we make of a chemical or product is essential for government regulation of such items as foods, drugs, cosmetics, pesticides, industrial chemicals, and medical devices. If a substance is claimed to be a food, it is governed by the food laws. If the exact same substance is packaged and labeled a drug, it is governed by the drug laws, not by the food laws. The laws that pertain depend on what use the manufacturer or seller specifies for the product. For example, hydrochloric acid is regulated as a household product when it is present in cleaning compounds, as a drug when it is used to treat people with low gastric acidity, as a hazardous industrial chemical when it is used in electroplating, and as a antibacterial adjuvant when it is used to enhance the germicidal activity of chlorine in swimming pools. Hydrochloric acid is natural when produced by the stomach and synthetic when made in the laboratory. Interestingly, all things tobacco are regulated by the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF), but since 2009 the Food and Drug Administration (FDA) is monitoring the advertising and content of cigarettes, emphasizing the toxic nature of cigarette ingredients and smoke. (The ATF was originally part of the Department of the Treasury and was primarily concerned with collecting revenue generated by taxes on the items it regulated. ATF still is involved in investigating the smuggling of cigarettes.)

Another example is boric acid, which occurs naturally as the mineral sassolite but also can be synthesized in the laboratory. It is regulated as a household product when used in laundry detergents, as a drug when sold as an antiseptic eyewash, as an insecticide when used to kill roaches, as an herbicide when applied to kill weeds, and as a flame retardant when used to fireproof fabrics. Many chemicals, such as hydrochloric acid and boric acid, fall into both drug and pesticide categories. Coumarin compounds, such as warfarin, are not only excellent rodenticides but are also valuable anticoagulant drugs that are used to prevent blood clots. Dichloro diphenyl dichloroethane (DDD), a close relative of dichloro diphenyl trichloroethane (DDT)—the infamous pesticide now banned in the United States—and itself an insecticide, was once used therapeutically to treat certain forms of adrenal cancer.

The important lesson to be learned from these examples should be apparent: The physical, chemical, and toxicologic properties of any chemical are totally independent of the category in which it is placed. The toxicity of boric acid is exactly the same when it is used as a drug as it is when it is used as a pesticide.

Although people are concerned about the products and effluents from the chemical industry, the class of man-made chemicals that is almost universally of concern is the category known as pesticides. Pesticides are substances, natural or synthetic, that are used to kill a plant, animal, insect, or other organism that has been determined to be undesirable for some economic, medical, or esthetic reason. Included in the pesticide category are insecticides, fungicides, herbicides, rodenticides, germicides, and a whole host of other “-cides.”

Countless chemicals are as toxic or more toxic than many of the pesticides, but the focus of fear centers on this group. Why? One reason is the tremendous amount of publicity given to reports of damage from the presence of pesticides in our environment and even in our own bodies. Another reason is that pesticides are used to kill living things and thus are labeled as poisons in the public mind. The concept of poison is considered by many people to be an all-or-none phenomenon: A chemical is either a poison or it is not, with no shades of gray in between. Nothing could be further from the truth. Such simplistic reasoning is counterproductive to an understanding of how and why chemicals cause harm. It also points up the fallacy of assigning blanket judgments of safety or harm to categories of chemicals.

CHEMICALS: “GOOD” AND “BAD”

A common misconception that must be overcome before an understanding of toxicity can be achieved is that chemicals made by nature are good and those made by humans are bad. Actually, toxicologists recognize that Mother Nature is far more ingenious than humans could ever be in devising toxic chemicals; it is also much more prolific. Of all the chemicals, the number of natural ones far exceeds the number made by humans. In addition, there are tens to hundreds of thousands of plants that botanists have not yet identified, much less characterized chemically. The voluminous literature on the toxic properties of naturally occurring chemicals that have been identified in food and nonfood plants, animals, and microorganisms supports an estimate that the fraction of natural chemicals that are toxic is at least as great as the fraction of synthetic chemicals that are toxic.

Some of the most toxic chemicals are produced by living organisms. A good example is botulin, the toxin produced by *Clostridium botulinum* organisms. One milligram (mg) of botulin (128 thousandth of an ounce) is capable of killing 20 million mice. It is estimated that the average oral lethal dose of botulin for an adult human is about 1 nanogram (ng) with one tablespoon containing enough toxin to kill over 3 *billion* people. Botulin toxin is available commercially as the active ingredient in prescription wrinkle injections (Botox® and others), and other medical uses have been found for it, including treating overactive bladder in children and treating muscle spasms. Studies have even been conducted for its efficacy in treating Parkinson’s disease. So although botulin is a very toxic compound, it has beneficial uses for humans when used correctly.