Introduction

Our world is changing rapidly and becoming more complex, disordered, and polluted. Economies are in disarray, crimes and conflicts are all too frequent, weapons are multiplying and spreading, and our lives are becoming ever more hectic and uncertain. Despite sustained efforts to control pollution, toxic gases are still spewing into our air, poisonous chemicals and nuclear waste products are piling up, fertilizers and pesticides are contaminating our water and food supplies, and our ecosystem is in a state of distress. And in spite of prolonged attempts to eradicate undesirable viruses, bacteria, and insects, the bugs are thriving and attacking us with greater impunity and intensity.

The explanation to our puzzling situation can be found in the discipline of thermodynamics. The First and Second Laws of Thermodynamics govern all processes and activities—from physical, chemical, and biological to economic, social, and intellectual. For historical reasons, they are called the Laws of Thermodynamics because they were discovered while studying heat and heat engines; yet they are extremely general Laws of Nature, vitally important to humankind.

This book—written from a physicist's standpoint—describes how the Laws of Thermodynamics apply to all areas of human endeavor, including chemistry, cosmology, medicine, education, agriculture, economics, technology, and ecology.

Once we grasp the essence of the Laws of Thermodynamics, we understand why our problems, from economic to environmental to social, are becoming increasingly intricate worldwide. Knowledge of these laws will help us comprehend how Nature works, and thus let us live in harmony with Nature and each other.

Solutions to our problems look very different depending upon whether we neglect or work within the Laws of Thermodynamics.

Thus it is important that we be aware of these laws and their effects on our lives, our society, and our environment so we can formulate policies that are not on a collision course with Nature's Laws.

Before human knowledge disintegrated into a myriad of specialties, science and philosophy were unified in their goal: to discover the truth about how Nature works and to arrive at fundamental Natural Laws through which we can present a unified view of Nature and our place in it. What we are left with today is philosophy without science, while science has been taken over by technology—applied science. As one scientist proclaimed: "Listen to the technology and find out what it is telling you."[1] But technology does not provide us with any principles of Nature, principles needed to derive a practical philosophy of life. For this we have to turn to the Laws of Thermodynamics.

Technology promised us a new world in which we would achieve control over our environment and the forces of Nature, gain access to unlimited and cheap energy and natural resources, and enjoy a youthful life free of diseases and health disorders. These promises have not materialized, and for good reason—because we live in a thermodynamic universe, one that cannot be controlled by our technologies but instead is controlled by the Laws of Thermodynamics.

Although these laws were discovered a century and a half ago, most people—including the educated—do not know enough about them. For example, in *Earth in the Balance*, Al Gore refers briefly to the First Law of Thermodynamics.[2] But he makes no mention of the Second Law, the one that affects us most.

The Laws of Thermodynamics—especially the Second Law—are frequently misunderstood and misrepresented in the literature, which is a serious disorder in human knowledge. Throughout this book, many popular misunderstandings of the Second Law are pointed out and corrected, including the widely held misconception that evolution violates it.

The main ideas of the First and Second Laws of Thermodynamics are explained in general terms in the first two chapters, along with some historical background. They provide the scientific foundation for the book's thesis.

In today's fast-changing environment, where technologies, theories, ideologies, fashions, and information quickly become obsolete

and are discarded, the Laws of Thermodynamics provide a good sense of stability and continuity. Not only have they withstood the test of time, they have become stronger and stronger as more and more supporting data have accumulated.

The Laws of Thermodynamics are based on two thermodynamic quantities: energy and entropy.

The First Law is about the conservation of energy. It says the amount of energy in the universe is constant. This implies that energy cannot be created or destroyed but can be transformed from one form to another. The expression "You can't get something for nothing" stems from this law.

The Second Law is about entropy. It stipulates that entropy increases in all processes irreversibly. Physicists identify entropy as a measure of the disorder of a thermodynamic system. In economic terms, the Second Law can be regarded as Nature's unyielding tax collector. It exacts a tax from all our activities by increasing the disorder of our thermodynamic system. Through increases in entropy, the Second Law controls and dictates the way all processes proceed in the universe. For this reason, it maintains a supreme position within the Laws of Nature. It demands our undivided consideration.

Whether we are physicists, biologists, economists, psychologists, or politicians; whether we are conservatives, liberals, or middle-of-the-roaders; whether we are technologists, environmentalists, deep ecologists, or ecofeminists; whether we are Africans, Americans, Asians, Australians, or Europeans; whether we are capitalists, communists, or socialists—we all feel and are affected by the cumulative effects of the physical, social, environmental, economic, and intellectual entropies within us and around us. Consequently, it is to our advantage to learn and understand what entropy is all about.

Three decades ago, ecologist René Dubos remarked that "the technological and other practical applications of science have been oversold." This eminent biologist believed that science would be more useful to humanity if it devoted more energy toward "the development of knowledge and attitudes that would help man to examine objectively, rationally, and creatively the problems that are emerging as a result of social evolution." He pointed out that "this aspect of science is given very low priority—if not neglected altogether—in universities and research institutes," adding that "we

hardly give any thought to the long-range consequences of our scientific and technological interventions into man's life and nature."[3] Dubos' observations are as relevant today as they were then.

Regrettably, the Laws of Thermodynamics have not received the emphasis they deserve. They can help us understand and tackle today's problems, particularly problems of our own making. Moreover, the discipline of thermodynamics includes important universal concepts, such as the irreversibility of natural processes. Our perspective on the world is very different if we view it as a reversible system subject to our control rather than an irreversible system governed by the Laws of Thermodynamics.

Once we become familiar with these laws, many previously unexplained phenomena and paradoxes become apparent. We see why time flows only one way, why we age irreversibly, why our lives are becoming increasingly complicated and uncertain, why we are experiencing "future shock," why we have less time for ourselves even though we are surrounded with more "timesaving" devices than ever before. We realize why so many promises and expectations have not come true. We are also able to foresee some dangers ahead.

The current educational environment and economic conditions have created a lot of specialists. Yet the concepts we have learned in our specialties, while useful and functional, have narrow ranges of applicability. They do not equip us with the ability to view the world in a general, comprehensive way. On the other hand, the discipline of thermodynamics—through its all-encompassing laws—allows us to see the whole picture. Indeed, it forces us to examine the total picture. Many of our gross errors in judgment have come about because we have considered only part of the thermodynamic system.

To deal with today's diverse but interconnected set of problems, we need a common set of general principles of Nature, principles that apply to all processes and activities. Then we will have a basis for discussing and tackling our pressing problems in economics, government, education, health care, transportation, technology, and ecology.