LABORATORY SAFETY

Theory and Practice

Edited by

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This book is a guide to provide general information concerning its subject matter; it is not a procedural manual. Laboratory safety is a rapidly changing field. The reader should consult current procedural manuals for state-of-the-art instructions and applicable governmental safety regulations. The Publisher does not accept responsibility for any misuse of this book, including its use as a procedural manual or as a source of specific instructions.

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Preface

There is an ironic relationship between the actual or potential hazards of certain acts or situations and the fear which they produce in the individuals involved. For example, the health hazards produced by habitual ingestion of alcohol or frequent cigarette smoking has been well-publicized for many years, yet the use of these substances is still almost mandatory in social situations. Furthermore, legislation to limit their use has continually met strong resistance. Similarly, neither are drivers forestalled from using their automobiles by the carnage on the highways, nor are a majority likely to observe the speed limits. Conversely, the very sight of a snake or shark, even on film, makes most people recoil in fear. This fear occurs despite the fact that the actual number of deaths caused by shark and snake attacks is a very small fraction of those caused by automobile accidents, cigarette smoking, or alcoholism. It is obvious, therefore, that the level of anxiety evoked often bears little relationship to the actual danger.

This disparity can be better understood if the question of what instills fear is examined. People generally fear what they do not understand or what they cannot control. Whether one smokes, drinks, or drives a car is self-controlled; whether a shark attacks is notoriously unpredictable and is controlled by the shark rather than the person.

A similar ironic relationship between hazard and anxiety is evident in a consideration of the scientific laboratory. There was, at one time, an enormous degree of anxiety in both public and scientific sectors over the hazards involved in genetic engineering. Although this fear still exists in a portion of the general public's mind, most scientists now feel that the actual danger is minimal.

For many years microbiologists have been engaged in research with virulent pathogens and toxins. Although these agents strike fear in the hearts of the nonscientific community, both the scientists and the technicians who work with them daily tend to view them with about as much fear as the general public views a cigarette or a speeding automobile. This overfamiliarity has, in several unfortunate instances, been one of the causes of accidents wherein laboratory workers were harmed. Because of the design of these laboratories and the fortuitous limitations of biological systems, an uncontrolled epidemic has never resulted from a laboratory accident. However, an injury to an individual laboratory worker or an epidemic resulting from man overriding nature's limitations should be avoided at all costs.

This book is intended to bridge the gap between fear of the unknown and familiarity bred of daily work. In the chapters that follow, the authors will present information on the hazards encountered in the laboratory by students, technicians, and scientists. The theoretical aspects of the hazards have been emphasized in order to increase the readers' understanding of the practices described, and to teach, by example, methods of risk assessment that can be applied to new technologies as they are translated from the scientist's mind to the laboratory bench.

The book is divided into three sections: (1) General Laboratory Safety; (2) Biological Laboratory Safety; and (3) Medical and Psychological Factors. The first section is subdivided into three chapters. Chapter 1 is a description of the hazards found in almost all laboratories, regardless of their specific functions. This includes the pertinent safety theories and practices. Chapter 2 is concerned with those almost ubiquitous compounds that are either toxic or carcinogenic. This area is becoming increasingly important as more and more laboratory reagents are recognized as carcinogenic. This chapter also stresses the insidious nature of these substances and provides guidelines for their use. Finally, Chapter 3 deals with radiation hazards which, because of the wider use of radioisotopic tracers and radioimmunoassays, have become a concern in many laboratories.

The second section of this book (Chapters 4–7) concentrates on safety in the biological laboratory. Most laboratory personnel are aware of the dangers in working with organisms such as smallpox, rabies, yellow fever, and even such exotic agents as crimean hemorrhagic fever or machupo virus. There are other areas of microbiological research, however, where the laboratory workers are not so fully cognizant of the dangers. One of these areas is the study of oncogenic viruses. Although a cause-and-effect relationship between viruses and cancer in humans has not been unequivocally established, the fact that this relationship exists in the rest of the animal kingdom must make laboratory personnel in this area aware of the problem. Therefore, Chapter 4 includes a discussion of this relatively complex group of viruses. Chapter 5 presents the readers with an approach to recombinant DNA research. It includes a general introduction to this new field of study and alerts investigators to the possible hazards associated with this research. Chapter 6 is a comprehensive approach to the design and function of biohazard laboratories. Such laboratories began almost simultaneously with the study of pathogenic microorganisms and acquired greater urgency because of the increased emphasis on oncogenic virus research of the late 1960s and early 1970s and the beginning of recombinant DNA research in the middle 1970s. Laboratory safety became a prime concern of the National Cancer Institute (NCI), which formed groups to conduct research on these problems and to disseminate information to workers in the field. Various agencies such as the Public Health Services (PHS), the National Cancer Institute, and the Office of Recombinant DNA Research (ORDR) used different names for laboratory containment levels, but these eventually evolved to four very similar levels used by all groups. Chapter 6 was written in relation to a virus oncology laboratory, but the levels of containment discussed can easily be translated to the nomenclature used by either the Center for Disease Control (CDC) or the ORDR. The specific levels of containment needed for various microbial pathogens are given in the Appendix at the end of the book. This is the latest listing by the CDC. The levels needed for various experiments in recombinant DNA research are not included in this book because the ORDR is in the process of reevaluating its current levels. As this book goes to press, it appears that work using the *E. coli* K12 system cloning the recombinant DNA will be lowered to the P1 containment level. Because of the wide variety of potential combinations that can be envisioned by researchers in the field, most of the innovative work in recombinant DNA research has to be judged on a case-by-case basis. An additional safety factor for recombinant DNA research is a requirement by ORDR that every institution engaging in this type of work have an Institutional Biosafety Committee (IBC) which reviews work in this area. Therefore, all laboratories should have an institutional committee that has the latest information and should be able to monitor individual safety practices. The final chapter in this section discusses the hazards relating to laboratory animals. The description of the often-overlooked possibility of contracting human diseases from uninfected experimental animals provides information for laboratory workers about a serious potential hazard. Other aspects common to animal research laboratories including hazards associated with experimentally infected animals, safe animal room practices, and animal-risk assessment are included.

The third section of this book contains a discussion of medical surveillance of persons at risk and the psychological factors involved in accident control. This section does not attempt to provide a detailed treatment of medical surveillance in the laboratory, but will provide an overview of the screening techniques available for the early detection of disease and personnel risks. Furthermore, this book does not discuss the techniques of cardiopulmonary resuscitation (CPR), since techniques such as this are most effectively acquired by taking an appropriate course. Such courses are readily available through the Red Cross, as well as many hospitals, medical institutions, and fire departments. Chapters 8 and 9 are directed to some of the topics discussed in earlier sections but approach hazards such as physical agents, toxins, carcinogens, and infectious agents from the viewpoint of the treating physician. Also included is a comprehensive list of chemical agents, their sources, their subsequent physical effects, and the accepted mode of medical surveillance. This list should provide the reader with a rapid means of ascertaining medically important information about commonly encountered laboratory chemicals.

With the introduction of recent genetic monitoring techniques, a greater awareness of the long term and subtle physical damage from mutagens has been brought to light. In Chapter 10, the reader will find an interesting discussion of various genetic screening tests available and their potential use for the evaluation of presumptive and actual mutagens. It is hoped that an insight into the realistic use, limitation, and potential of genetic screening may be obtained by the reader. The final chapter of the book discusses human behavior as related to laboratory safety. The author provides a brief review and discussion designed to identify and isolate important behavioral factors that can cause accidents. This chapter is included as an acknowledgment of the important basic concept that even the best equipped and designed laboratory with the most stringent hypothetical safety standards is only as "safe" as the people who work in that laboratory make it. The human factor ("safe practices") cannot be overstated. In the final analysis, if the principles discussed in *this* chapter are disregarded, the information contained in the rest of the book will, in time, be forgotten and laboratory safety will remain an administrator's theory rather than a laboratory reality.

The editors would like to thank Ms. Angela Venuto for her time and energy, attentiveness to detail, and persistence. Without her help, the transition from a proposed book to reality would never have been completed.

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PART ONE
GENERAL LABORATORY SAFETY

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Chapter One

Physical, Chemical, and Fire Safety

NORMAN V. STEERE

LABORATORY SAFETY: THEORY AND PRACTICE

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I. INTRODUCTION

Epidemiology provides a framework for developing a rational approach to safety and accident prevention. Just as the disease process is an interaction of susceptible host, environment, and disease agent, the causation of injury is an interaction of several factors and should not usually be blamed primarily on a single factor, such as an unsafe condition or an unsafe act.

The parallel between disease causation and injury causation was first elucidated in 1949 by the epidemiologist John Gordon. He stated that injury, like disease, requires a susceptible host, an environmental reservoir, and a third factor corresponding to the disease agent. In an injury, a dose of energy in excess of the damage threshold of the susceptible host can be likened to the infective dose of a pathogen. The amount of energy necessary to cause injury will vary with the damage threshold of the host, just as the infective dose varies in disease causation. An example of injury caused by direct energy transfer is the electrically induced injury that occurs when a person's body receives electrical energy in excess of the "let-go" current level for that person. Haddon elaborated on the concept of injury resulting from direct transfer of energy and added a classification for damage caused indirectly through interference with the body's ability to transfer energy within body systems (Haddon *et al.,* 1964). For example, sulfuric acid causes tissue destruction by direct transfer of energy, but carbon monoxide causes a chemical asphyxiation indirectly by interfering with the ability of hemoglobin to transfer oxygen to body tissues. Extreme cold can cause injury directly by frostbite and freezing of body tissues or indirectly by hypothermia, which is a failure of the body's thermoregulation system.

The types of energy or hazards that can cause damage directly or indirectly have been classified (Steere, 1974) as follows:

Form of energy or hazard	Modes of action
Mechanical energy	Direct
Electrical energy	Direct
Ionizing radiation	Direct and indirect
Nonionizing radiation	Direct and indirect
Biological organisms	Indirect
Chemicals	Direct and indirect
Atmospheric pressure differentials	Indirect
Thermal	Direct and indirect
Fire	Direct and indirect

Although the major emphasis of this book is on biological hazards, radiation hazards, and hazards from toxic chemicals, most laboratories also