Principles and Methods of Sterilization in Health Sciences

EXCERPT:—

The mode of life of modern men is profoundly influenced by hygiene and medicine and the principles resulting from the discoveries of Pasteur. The promulgation of the Pasteurian doctrines has been an event of the highest importance to humanity. Their application rapidly led to the suppression of the great infectious diseases which periodically ravaged the civilized world, and of those endemic in each country.

—ALEXIS CARREL: *Man The Unknown*

Second Edition

Principles and Methods of Sterilization in Health Sciences

By

JOHN J. PERKINS, M.S., LL.D., F.R.S.H.

Vice President
American Sterilizer Company
Erie, Pennsylvania

CHARLES C THOMAS • PUBLISHER

Springfield • *Illinois* • *U.S.A.*

Published and Distributed Throughout the World by

CHARLES C THOMAS • PUBLISHER
2600 South First Street
Springfield, Illinois, 62717, U.S.A.

ISBN 978-0-398-07852-2

Library of Congress Catalog Card Number: 73-19637

First Edition, First Printing, 1956
First Edition, Second Printing, 1960
First Edition, Third Printing, 1963
First Edition, Fourth Printing, 1965
Second Edition, First Printing, 1969
Second Edition, Second Printing, 1970
Second Edition, Third Printing, 1973
Second Edition, Fourth Printing, 1976
Second Edition, Fifth Printing, 1978
Second Edition, Sixth Printing, 1980
Second Edition, Seventh Printing, 1982
Second Edition, Eighth Printing, 1983

Printed in the United States of America
R-1

PREFACE TO THE SECOND EDITION

TEN YEARS have elapsed since the appearance of the first edition of this book. During that time many advances have occurred in the field of sterilization, with particular emphasis upon medical-surgical applications. These developments rendered much of what had been written obsolete, and made necessary an extensive revision of the text including the graphics and illustrations. Nearly every chapter has undergone considerable change, and new knowledge relating to automation, mechanical equipment, methods, techniques, and procedures has been added.

Several sections have been reworked completely, particularly those dealing with the thermal destruction of microorganisms, processing of instruments, the central service department, and ethylene oxide gas sterilization. The impact of prepackaged, presterilized disposables on the modern hospital has been the cause for deletion or restricted treatment of certain material such as processing of surgeon's gloves, syringes and needles, and infant formulas.

Although the text and illustrations have been altered extensively, the structure of the book remains unchanged. Moreover, the general objective remains the same: to offer a coherent reference guide for sterilization practices in hospitals, clinics, laboratories, allied institutions and services. The tremendous strides being made in the field of medicine and in the hospital care of patients make it increasingly evident that decontamination, sterilization, disinfection, and environmental sanitation are subjects upon which lives depend. An adequate understanding of the many problems of sterilization, disinfection, and the aseptic barrier is a necessity for those who must shoulder the responsibility for the preparation and use of sterile supplies in our hospitals. The author has intentionally omitted any discussion on radiation sterilization for the simple reason that it is considered impractical to attempt to cover the subject in any depth in one chapter of the book. Also, equipment required for the use of high-energy ionizing radiations, whether in the form of a linear accelerator machine or a cobalt-60 source, is costly and currently impractical for installation in hospitals. An excellent source of information on radiation is the U.S. Atomic Energy Commission and Atomic Energy of Canada, Ltd.

A further word of explanation seems desirable for the large number of bibliographic references attached to the majority of the chapters. It is believed that for the serious student, the text may not be sufficient, and he should, therefore, have the opportunity of examining original papers and thoughtful reviews that give a more detailed picture.

JOHN J. PERKINS

Erie, Pennsylvania

PREFACE TO THE FIRST EDITION

THIS BOOK is an attempt to integrate basic principles upon which conventional sterilizing processes depend with practical methods for the preparation and sterilization of materials and supplies. It was written primarily to serve as a reference guide for sterilization practices in hospitals, clinics, laboratories, allied institutions and services. It is in this institutional environment that we find a host of professional and nonprofessional workers daily depending upon the science of sterilization and surgical asepsis as the chief means of protecting the patient against the ravages of infectious disease. The need for helpful information on the subject is acute, particularly among operating room supervisors and central service supervisors—the key persons largely responsible for sterilization techniques in hospitals.

The goal of the author has been to systematize the study, giving all of the important principles and methods of which he is aware, at the same time keeping the work within the limits of a textbook rather than an extensive reference volume. Many important references on the subjects of sterilization and disinfection have been freely consulted. Without the long list of reference material this book should not have been written. Any subject as extensive as that of sterilization which, conservatively, covers the past seventy-five years, is not the work of a few, but many people. Scientific minds pave the way and open the door to progress, but actual advancement does not take form until industry through the designing engineer is able to build the necessary equipment. Even then, the maximum benefits of progress in sterilization are not realized by the patient until hospital personnel are thoroughly trained to apply the principles and to intelligently operate the equipment.

The question may logically arise as to whether nurses or nursing students, as a group, are sufficiently prepared to profit by the study of scientific journals and technical publications. It is the author's opinion that if nurses are to be charged with the responsibility for sterilization in hospitals they must be encouraged to read and search for pertinent reference material. Certainly it is desirable to stimulate an open-minded, questioning attitude on the part of all nurses for the subject of sterilization. The operating room supervisor and the central service supervisor particularly should realize that sterilization is an expanding subject with the constant addition of new knowledge, the discarding of old theories or their reinterpretation in the light of new experimental evidence.

For any errors, omissions or misstatements found in this book, the author must assume full responsibility. The long hours spent in the preparation of the manuscript have been a work of love rather than labor. It is hoped that it will be found useful in some measurable degree by those for whom it is intended.

ACKNOWLEDGMENTS

THE AUTHOR wishes to acknowledge his indebtedness to the American Sterilizer Company, for the generous grant of time expended in preparing the manuscript, and for permission to use the large number of photographs and diagrams from which many of the illustrations have been made. An expression of gratitude is also due the American Sterilizer Company for permission to use certain copyrighted material from the Textbook on Sterilization by the late W. B. Underwood.

Sincere thanks and appreciation are extended to the friends and colleagues of the author who have rendered valuable assistance, in particular: to Miss Edna Prickett, of the American Hospital Association, for review and criticism of the sections dealing with surgical sterilization; to Miss Marian Fox, of the American Hospital Association, and Miss Margaret Giffin, formerly of the National League of Nursing, for the opportunity to observe the everyday problems of the operating room supervisor and the central service supervisor through the medium of Institutes; to the Research Staff of the American Sterilizer Company for skillful assistance in the accumulation of material and the reading of proof.

Grateful acknowledgment is also made to the many authors whose works have been quoted in this book. Thanks are extended to the various publishers who have generously granted permission for the reproduction of illustrations and quotations from their publications. In these cases, specific acknowledgment has been made in the appropriate places throughout the text.

In the preparation of this revision, the author has profited greatly from the kind suggestions and generous technical advice received from many friends and colleagues both in the United States and abroad. It is a pleasure to record my appreciation of the help and assistance rendered by the Research and Development staff of the American Sterilizer Company; also for permission to excerpt copyrighted material from the *Journal of Hospital Research*. Grateful appreciation is extended to the following for their substantial contributions to the text and for resource information and data:

Ultrasonics—

G. G. Brown,
Senior Engineering Consultant,
American Sterilizer Company.

Ethylene Oxide—

R. S. Lloyd, M.S.,
Research Assistant,
American Sterilizer Company.

Pyrogens—

S. A. Marcus, Ph.D.,
Department of Microbiology,
University of Utah.

Surgical Scrubs—

P. B. Price, M.D.,
Emeritus Professor of Surgery,
University of Utah.

Surgical Environment—

Miss E. A. Prickett, B.S., R. N.,
American Hospital Association.

Chemical Disinfection—

E. H. Spaulding, Ph.D.,
Department of Microbiology,
Temple University Medical Center.

Central Service Department—

Mrs. M. D. Young, B.S., R. N.,
Nurse Consultant,
American Sterilizer Company.

Special thanks are due John R. Raup for general assistance in the preparation of the manuscript, the procurement of illustrations, and the reading of proofs. Acknowledgment is also due Mrs. E. H. Garwood for her splendid assistance in the preparation of graphs, charts, and other illustrative material. Finally, the author wishes to thank his secretary, Mrs. Goldie Kreider, for devoted assistance in organizing material and for typing the many manuscript revisions.

J.J.P.

CONTENTS

Principles and Methods
of Sterilization
in Health Sciences

Chapter 1

HISTORICAL INTRODUCTION

IT HAS OFTEN been said that nothing is more difficult than the beginning. This remark seems particularly appropriate as the opening phrase to the Historical Introduction on the subject of sterilization. To be sure, one cannot claim that related material is lacking as a preparatory measure, because the literature contains a wealth of information dealing either directly or indirectly with the subject. However, any attempt to trace the origin of various practices which form the basis of our modern concept of sterilization leads eventually to the conclusion that gradual development of the art has been so closely allied with the development of microbiology that it is difficult to discuss the former without bringing into the picture more than the desirable amount of the latter. Just as the science of microbiology is said to have originated from the various attempts to solve the origin of life and the origin of death, so has the advancement of our knowledge of sterilization kept pace with each important contribution to these age-old problems of nature. To the historian, it is also evident that the many investigations and researches which have led us to our present state of knowledge on this subject, as well as that of microbiology, were actually stimulated by certain controversies and ideas originating hundreds of years before the beginning of the Christian era.

OUR ANCIENT HERITAGE

From the dawn of recorded history man appears to have practiced in one form or another the process of purification or disinfection, the latter a precursor of sterilization. The use of antiseptics such as pitch or tar, resins and aromatics was widely employed by the Egyptians in embalming bodies even before they had a written language. From the work of Herodotus[1] (484-424 B.C.), there are indications that the Egyptians were acquainted with the antiseptic value of dryness resulting from the use of certain chemicals such as niter and common salt. The fumes of burning chemicals were also used by the ancients for deodorizing and disinfecting purposes. Of early importance was sulfur, apparently the first of the useful chemicals to be mentioned. In the Odyssey[2] the following passage may be found:

> *To the nurse Eurycleia then said he:*
> *"Bring cleansing sulfur, aged dame, to me*
> *And fire, that I may purify the hall."*

The purification of premises and the destruction of noxious and infectious material by fire also seem to have originated among the Egyptians. The cremation of bodies of animals and of persons, especially in the case of war, was often resorted to by the ancients as a means of their disposal, as well as a way of destroying putrefactive odors.

Moses was the first to prescribe a system of purification by fire, and we learn from the books of Leviticus and Deuteronomy that he also developed the first system for the purification of infected premises. The stern mandates given by Moses (about 1450 B.C.) on the disposal of wastes, camp sanitation, treatment and prevention of leprosy, the touching of unclean objects or eating of unclean foods, formed the basis of the first sanitary code as established by the ancient Hebrews. It is noteworthy that they forbade tattooing (Lev. 19:28) with its attendant risk of needle-transmitted hepatitis, and it is probable that they suspected the role of flies in the transmission of disease.[3] From the precepts as laid down in the Mosaic law are based the various systems of purification of the succeeding ages.

History has recorded that the thinkers of antiquity never seem to have doubted that under favorable conditions life, both animal and vegetable, might arise spontaneously. Certain of the early Greek philosophers held the theory that animals were formed from moisture. Empedocles (450 B.C.), an early advocate of fumigation as a means of combatting epidemics, attributed to spontaneous generation all of the living beings which he found inhabiting the earth. Aristotle (384 B.C.) also asserted that "sometimes animals are formed in putrefying soil, sometimes in plants, and sometimes in the fluids of other animals." He also formulated a principle that "every dry substance which becomes moist, and every moist body which becomes dried, produces living creatures, provided it is fit to nourish them." During this era it is worthy of note that Hippocrates (460-370 B.C.), the greatest of all physicians, who was responsible for the dissociation of philosophy from medicine, recognized the importance of boiled water for irrigating wounds, the cleansing of the hands and nails of the operator, and the use of medicated dressings for wounds.

An early exponent of the germ theory of disease was Marcus Terentius Varro (117-26 B.C.), one of Caesar's more competent physicians. His *Rerum Rusticarum* contains these words: "Small creatures, invisible to the eye, fill the atmosphere, and breathed through the nose cause dangerous diseases."[4]

THE MIDDLE AGES

In the period from 900 to 1500 A.D., progress from the standpoint of noteworthy contributions having a direct bearing on the development of the art of sterilization was virtually at a standstill. For medicine this period is also regarded as an age of decadence and stagnation. Filth, pestilence, and plague ravaged all Europe in the Middle Ages. Attempts were made to combat the pestilence in hospitals, lazarettos, and infected houses by means of cleansing solutions, aeration, the smoke of burning straw, fumes of vinegar, and, not the least, by the fumes of sulfur, antimony, and arsenic. The Middle Ages witnessed the rise of the monastic infirmaries under the influence of the early Church. It is believed that the modern doctor-staffed hospitals had their true origin in these monastic infirmaries comprising patient wards, apothecary shops, and other facilities.

In 1546, Fracastorius, the world's first epidemiologist, published his famous work *De Contagione,* which dealt with airborne pestilence. He presumed the existence of imperceptible "seeds of disease which multiply rapidly." Moreover, he declared that diseases were spread in three ways: by direct contact, by handling things that infected persons had handled previously, and by transmission from a distance.[5]

THE DISCOVERY OF BACTERIA

The existence of bacteria was considered possible by many people long before their discovery. However, actual proof of their existence had to await the development and construction of a compound microscope suitable for the observation and study of forms of microbial life. For this achievement, credit must be given to Antonj van Leeuwenhoek, a Dutch linen draper, for marked perfection of lenses of short focal distance with which he was able to see for the first time some of the larger forms of bacteria. In 1683, he observed and described a great variety of microbial forms in various body fluids, intestinal discharges from animals, water, and beer with a high degree of accuracy and painstaking detail. He also made important contributions to microscopic anatomy and is regarded by certain authorities as the real discoverer of the blood corpuscles.[6] Leeuwenhoek's observations and development of the microscope provided the foundation of bacteriology and reopened the question concerning the causation of fermentation and disease.

THE DOCTRINE OF SPONTANEOUS GENERATION

Following the discovery of bacteria, the age-old question of spontaneous generation of living things again became a subject for discussion. Some few individuals did combat the theory, but the belief was general that bacteria did originate spontaneously and this belief persisted until Louis Pasteur finally settled the question with convincing experimental data in 1862. One of the early opponents of the theory was L. Spallanzani,[7,8] who in 1765 demonstrated that boiling an infusion of decomposable matter for 2 minutes did not suffice to destroy all the microbes; but when the infusion was placed in a hermetically sealed flask and boiled for an hour, no generation of microbes or fermentation occurred, so long as the flask remained sealed. Although Spallanzani proved to his own satisfaction that vegetative power does not exist in inanimate material, it was still maintained by some, notably John Needham

FIGURE 1-1. Antonj van Leeuwenhoek. (Courtesy Lambert Pharmacal Co.)

(1713-1781) and George Buffon (1707-1788), that the boiling process had weakened or destroyed the "vegetative force," thereby preventing spontaneous generation from taking place.

The attack on spontaneous generation was continued in 1836 by Franz Schulze,[9] who failed to find evidence of living organisms in boiled infusions to which air had been admitted only after passage through sulfuric acid. Similar experiments were conducted by Theodor Schwann,[10] in 1837, except that the air admitted to the infusions was first heated to a high temperature, but the results were the same—no evidence of fermentation or bacterial growth. In connection with the work of Schwann, it is interesting to note that he considered the process of fermentation could be arrested or inhibited by an agent capable of destroying fungi, such as heat or potassium arsenate. Because of this belief, Schwann is regarded by certain authorities as the founder of the science of disinfection.[11]

In 1854, H. Schroeder and T. von Dusch[12] made additional contributions in favor of the opposing forces to the theory of spontaneous generation. These workers employed a new technique of admitting air into flasks of boiled infusions by filtering the air through a layer or plug of cotton wool. This was

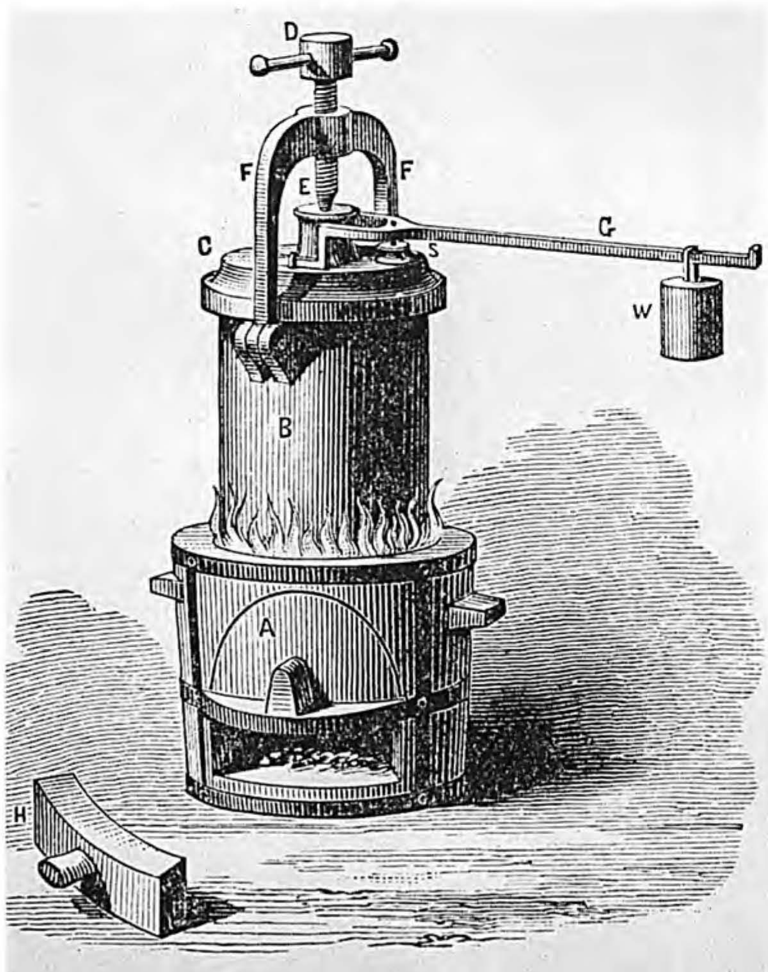

FIGURE 1-2. Papin's "Digester." Invented by Denys Papin in 1680—a collaborator of Robert Boyle in study of pneumatics. The "digester" consisted of a vessel, B, capable of being tightly closed by screw, D, and lid, C, in which food could be cooked in water raised by furnace, A, to temperature of any desired safe pressure of steam. Pressure was determined and limited by weight, W, on safety valve lever, G. Papin is given credit for having first made use of safety valve to control pressure of steam. (Courtesy Cornell Univ. Press.)

done to combat the argument against any possible change in the properties of the air which could have occurred in the experiments of Schulze and Schwann, and which might give rise to a condition unfavorable to the support of life. Although the results showed that sterile solutions were obtained by this method, it was later demonstrated that the same procedure was unsuccessful in preventing fermentation of milk, meat, or egg yolk unless these materials were subjected to prolonged boiling at 100°C, heated in an oil bath to 130°C or heated in Papin's "digester" under a pressure of 15 to 75 pounds (see Fig. 1-2).

By the year 1859 the problem of spontaneous generation was still in a state of uncertainty. The primary issue at stake was decisive proof of the presence of microbes in the atmosphere. The controversy was further aggravated by the appearance of a publication entitled *Heterogenie,* by F. A. Pouchet.[13] Apparently the author had repeated the experiments of Schulze and Schwann and his results were diametrically opposed to the findings of the earlier investigators. Pouchet also ridiculed the assumption of organisms being present in the atmosphere—a view in direct conflict with the current reasoning of Pasteur that microorganisms responsible for fermentation came from outside the fermenting material.

LOUIS PASTEUR

For an account of Pasteur's contributions to the development of the art of sterilization, it is necessary to begin with the year of 1860. Here we find Pasteur, having previously completed his brilliant researches on the microbic cause of fermentation, now ready to begin his epoch-making studies on the problem of spontaneous generation. He began his attack with a microscopic investigation of atmospheric air, and with the aid of the most ingenious devices he demonstrated that the air in different localities differed in its content of microorganisms. His paper published in 1862,[14] "On the Organized Corpuscles Existing in the Atmosphere," was destined, according to some scientific minds of that day, to remain forever as a classic. With a severity typical

FIGURE 1-3. Pasteur dictating notes on silkworm disease to his wife (1868). (Courtesy The Upjohn Co.)