

Disinfection and Sterilization

G. SYKES M.Sc. (Lond.), F.R.I.C.

With a Foreword by

SIR GRAHAM WILSON

M.D., F.R.C.P., D.P.H.

*lately Director of the Public Health
Laboratory Service*

SECOND EDITION

REVISED AND ENLARGED

LONDON

E. & F. N. SPON LTD

22, Henrietta Street, W.C.2

First Published 1958

Second Edition 1965

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Printed in Great Britain at

the Pitman Press, Bath

Catalogue Number 16/0856/7

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CHEMISTRY SERIES

Edited by: H. M. BUNBURY, M.Sc., F.R.I.C.

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FOREWORD

by

SIR GRAHAM WILSON

IN my foreword to the first edition in 1958, I gave a brief review of the history of disinfectants during the last 100 years, and noted the comparatively recent introduction not only of new germicidal agents but of new ways of sterilization, disinfection and preservation of materials in common use. Because Mr. Sykes had fulfilled his task admirably, I had no hesitation in commending his book to those who, whether engaged in medicine, pharmacy, sanitary engineering, dairying, brewing or the food industry, wanted reliable and up-to-date information to help them in the multitude of problems that beset them in their various fields of activity. The fact that a second edition has been called for in so short a time leaves no doubt that the book is meeting a widespread need.

It would probably be true to say that more attention is being paid now to the use of physical than to chemical methods of removing, immobilizing, or destroying unwanted micro-organisms. Experience of chemical disinfectants, particularly in medicine and the dairy industry, has shown their inferiority to heat in the destruction of bacteria; and it is only right therefore that Mr. Sykes should expand, as he has done, the sections of his book dealing with such physical means of sterilization and disinfection as heat, filtration, and the various forms of irradiation and ultrasonic treatment now available.

He is wise too to set his face against the use of such imprecise terms as "Sterilant" and "Sanitization". The definitions that he has given of the terms he employs are ones that are etymologically correct and will be accepted by other scientific workers. To call a substance a sterilant that does not sterilize is misleading; and what the term sanitization means beyond mere cleansing it is impossible to say. It throws no light on the degree of bacterial destruction involved, if any, and it is but one more example of the use of a long, inexact word of Latin derivation to obscure the mental haziness of those who have never troubled to think what they mean.

Personally I welcome the publication of this new and enlarged version of Mr. Sykes's original book. It is an expression of his erudition and his literary ability to which all will pay tribute. It is doubtful whether anyone else in this country could have dealt so competently with so many controversial issues in so many different fields; and I hope the book will meet with the success that it deserves.

GRAHAM S. WILSON

PREFACE TO SECOND EDITION

ALTHOUGH it is less than six years since the first edition of this book appeared, investigations in nearly all of the fields has continued at an increasing rate and much new thinking has taken place. This second edition is, therefore, something more than the first edition "brought up to date". Most of the chapters, although retaining substantially the same titles and order of presentation, have been largely rewritten with emphasis on the revised outlooks and the newer evidences without sacrificing unduly the earlier foundational references.

In particular, attention is drawn to the changing attitudes towards the testing of disinfectants and antiseptics, as given in Chapters 3 and 4, and the substantial new information which has come to light concerning methods of sterilization, with special emphasis on several aspects of sterilization by heat and by radiations; new agents for gaseous sterilization has also been introduced.

In Part V dealing with Chemical Disinfectants the sections on 'germicidal' soaps and disinfectant fluids has been completely remoulded and new data has been added in other section. Similarly in the chapter on surface active compounds a new section on amphoteric compounds has been added, together with some new information on quaternary ammonia compounds. The chapter on the heavy metals salts has also been extended.

Finally, a great deal more is now known about various aspects of preservation, particularly in relation to foods and pharmaceutical materials and this has been mainly included in a rewritten chapter (17) on the subject.

Again I wish to thank my various colleagues and associates who have given valuable assistance and information. In particular I would commend Miss Barbara Hooton and Mr. R. Smart for their help in preparing the manuscript and in checking the proofs.

G. SYKES

Boots Pure Drug Co. Ltd.,
Microbiology Division,
Standards Department,
Nottingham.

July, 1964

PREFACE TO FIRST EDITION

WITH the many advances which are being made in the broad fields of hygiene, sanitation and medicine and the profound changes which are taking place in our everyday mode of living, more and more emphasis is being placed on the need for adequate and reliable methods for disinfection, preservation and sterilization. It is a matter which impinges on the social and economic welfare of the whole community and is seen in the continuous scientific and technical progress being made in the various sections of the food, pharmaceutical and chemical industries as well as in the several disciplines of medicine and public health.

The greatest advances have undoubtedly occurred during the last two or three decades and it is the purpose of this book to present a considered appraisal of these developments. In approaching the subject I have confined myself – if confined is still the right word to use in such a large field – to the chemical and physical aspects of disinfection and sterilization to the almost total exclusion of any discussion on chemotherapy or the role of antibiotics; these topics are now almost separate subjects in themselves and have already filled several volumes.

Perhaps it may appear that an unduly large proportion of the book is taken up with discussions on the theory and mode of action of disinfection, not only in the chapter bearing that title but also in other chapters; but this is deliberate, for this aspect of the subject is gradually assuming greater importance, and it seems that future developments are likely to take place from such considerations rather than from the erstwhile more empirical approach. It also seemed desirable to collect together as many as possible of the tried and proved methods of testing disinfectants and antiseptics, and this is done in Chapters 3 and 4; attention is also given in these chapters to some of the more historical methods of testing and to other potentially useful ones. With regard to the techniques available for disinfection, preservation and sterilization, I have endeavoured to cover the most recent developments in both the chemical and physical fields as completely as possible, devoting individual chapters to the important topics of radiation sterilization and the disinfection of viruses.

The usual abbreviations have been adopted for expressing units of time, volume, etc., and temperatures are quoted in degrees Centigrade except in the few places where they are specifically stated to be in degrees Fahrenheit. For bacterial nomenclature I have used the Topley and Wilson system, preferring *Pseudomonas pyocyanea* to *Pseudomonas aeruginosa*, *Chromobacterium prodigiosum* to *Serratia marsescens* and so on, but using *Escherichia coli* instead of *Bacterium coli*.

In preparing the text I have made frequent reference to the literature, and in this respect have greatly appreciated the facilities available through the libraries of Boots Pure Drug Co. Ltd. I wish to record thanks to Dr. R. S. Hannan and Dr. Margaret Thornley for their useful criticisms of the manuscript of the chapter on Radiation Sterilization, and to Dr. L  is Dickinson who has given similar help with the chapter on the Disinfection of Viruses. I am also indebted to several authors and publishers for permission to reproduce certain Tables and Figures, in particular to the editors of the *Proceedings of the Royal Society* for permission to reproduce Plate I, to Dr. Harriette Chick and the editors of the *Journal of Hygiene* for Figure 1 and Table I, to Dr. R. M. Savage and the editor of the *Journal of Pharmacy and Pharmacology* for Figure 6, to Dr. G. E. Stapleton, Dr. M. Levine and the editor of the *Journal of Bacteriology* for Figures 10, 15 and 16, and to the editors of the *Journal of Applied Bacteriology* for Figure 17 and Table 16. The help given by Mrs. Maureen Pole, Miss Pamela Chapman, Mr. D. V. Carter, Mr. H. M. Bunbury and other colleagues in assembling the manuscript and checking the proofs has been invaluable and I thank them all. Finally, I must mention Mr. C. E. Coulthard, under whose guidance I first began to learn something of the subjects about which I now venture to write.

G. SYKES

Boots Pure Drug Co. Ltd.,
Microbiology Division,
Standards Department,
Nottingham.

March, 1958.

LIST OF LITERATURE ABBREVIATIONS

<i>Acta microbiol., hung.</i>	Acta microbiologica, Academicæ Scientiarum Hungaricæ
<i>Acta path. microbiol. scand.</i>	Acta pathologica et microbiologica scandinavica
<i>Adv. appl. Microbiol.</i>	Advances in Applied Microbiology
<i>Adv. food Res.</i>	Advances in Food Research
<i>Amer. J. clin. Path.</i>	American Journal of Clinical Pathology
<i>Amer. J. Hyg.</i>	American Journal of Hygiene
<i>Amer. J. med. Sci.</i>	American Journal of the Medical Sciences
<i>Amer. J. Obstet. Gynec.</i>	American Journal of Obstetrics and Gynecology
<i>Amer. J. Ophthal.</i>	American Journal of Ophthalmology
<i>Amer. J. Path.</i>	American Journal of Pathology
<i>Amer. J. Pharm.</i>	American Journal of Pharmacy
<i>Amer. J. Physiol.</i>	American Journal of Physiology
<i>Amer. J. publ. Hlth</i>	American Journal of Public Health
<i>Amer. J. Surg.</i>	American Journal of Surgery
<i>Amer. Rev. Tuberc.</i>	American Review of Tuberculosis
<i>Analyst</i>	The Analyst
<i>Ann. appl. Biol.</i>	Annals of Applied Biology
<i>Ann. Inst. Pasteur</i>	Annales de l'Institut Pasteur
<i>Ann. N.Y. Acad. Sci.</i>	Annals of the New York Academy of Sciences
<i>Ann. Rev. Biochem.</i>	Annual Review of Biochemistry
<i>Ann. Rev. Microbiol.</i>	Annual Review of Microbiology
<i>Antonie van Leeuwenhoek J. Microbiol. Serol.</i>	Antonie van Leeuwenhoek Journal of Microbiology and Serology
<i>Antibiot. Chemoth.</i>	Antibiotics and Chemotherapy
<i>Appl. Microbiol.</i>	Applied Microbiology
<i>Arch. Biochem.</i>	Archives of Biochemistry
<i>Arch. Dermatol. Syphilol.</i>	Archives of Dermatology and Syphilology
<i>Arch. ind. Hyg.</i>	Archives of Industrial Hygiene and Occupational Medicine
<i>Arch. Mikrobiol.</i>	Archiv für Mikrobiologie
<i>Arch. Surg., Lond.</i>	Archives of Surgery, London
<i>Aust. J. exp. Biol. med. Sci.</i>	Australian Journal of Experimental Biology and Medical Science
<i>Bact. Rev.</i>	Bacteriological Reviews
<i>Biochem. J.</i>	Biochemical Journal
<i>Biochem. Z.</i>	Biochemische Zeitschrift
<i>Biodynamica</i>	Biodynamica
<i>Biol. Abs.</i>	Biological Abstracts
<i>Biometrics</i>	Biometrics
<i>Boll. Ist. sieroter. milan</i>	Bollettino dell'Istituto sieroterapico milanese
<i>Brit. J. exp. Path.</i>	British Journal of Experimental Pathology
<i>Brit. J. ind. Med.</i>	British Journal of Industrial Medicine
<i>Brit. med. J.</i>	British Medical Journal
<i>Brit. J. Pharmacol.</i>	British Journal of Pharmacology and Chemotherapy

<i>Brit. J. Urol.</i>	British Journal of Urology
<i>Brit. Vet. J.</i>	British Veterinary Journal
<i>Bull. Acad. méd., Paris</i>	Bulletin de l'Académie de médecine
<i>Bull. Hyg.</i>	Bulletin of Hygiene, London
<i>Canad. J. med. Sci.</i>	Canadian Journal of Medical Sciences
<i>Canad. J. Microbiol.</i>	Canadian Journal of Microbiology
<i>Chem. Abs.</i>	Chemical Abstracts (American)
<i>Chem. Fabrik</i>	Chemische Fabrik
<i>Chem. & Ind.</i>	Chemistry and Industry
<i>Compt. rend. Acad. sci.</i>	Comptes rendus hebdomadaires des séances de l'Académie des sciences
<i>Compt. rend. Soc. Biol.</i>	Comptes rendus hebdomadaires des séances de la Société de biologie
<i>Dansk Tidss. Farm.</i>	Dansk Tidsskrift for Farmaci
<i>Deut. med. Woch.</i>	Deutsche medizinische Wochenschrift
<i>Drug Stds</i>	Drug Standards
<i>Elect. Engng, N.Y.</i>	Electrical Engineering, New York
<i>Electronics</i>	Electronics
<i>Exp. cell Res.</i>	Experimental Cell Research
<i>Food Ind.</i>	Food Industry
<i>Food Mfg.</i>	Food Manufacture
<i>Food Res.</i>	Food Research
<i>Food Technol.</i>	Food Technology
<i>Gen. elec. Rev.</i>	General Electrical Reviews
<i>Gesund. Desinf.</i>	Gesundheitswesen und Desinfektion
<i>Heat. air Treat. Engr</i>	Heating and Air Treatment Engineer
<i>Heat. Pip. air Cond.</i>	Heating, Piping and Air Conditioning
<i>Heat. vent. Engng</i>	Heating and Ventilating Engineering
<i>Hosp. Engr</i>	The Hospital Engineer
<i>Ind. Chem.</i>	Industrial Chemist
<i>Ind. engng Chem.</i>	Industrial and Engineering Chemistry
<i>Ind. engng Chem. (Anal.)</i>	Industrial and Engineering Chemistry (Analytical Edition)
<i>Int. J. appl. Rad. Isot.</i>	International Journal of Applied Radiation and Isotopes
<i>Iowa engng exp. Sta. Bull.</i>	Iowa Engineering Experimental Station Bulletin
<i>Iowa State Coll. J. Sci.</i>	Iowa State College Journal of Science
<i>Johns Hopkins Hosp. Bull.</i>	Johns Hopkins Hospital Bulletin
<i>J. Amer. chem. Soc.</i>	Journal of the American Chemical Society
<i>J. Amer. diet. Ass.</i>	Journal of the American Dietary Association
<i>J. Amer. med. Ass.</i>	Journal of the American Medical Association
<i>J. Amer. pharm. Ass. (Pract.)</i>	Journal of the American Pharmaceutical Association (Practical Edition)
<i>J. Amer. pharm. Ass. (Sci.)</i>	Journal of the American Pharmaceutical Association (Scientific Edition)
<i>J. Amer. vet. med. Ass.</i>	Journal of the American Veterinary Medical Association
<i>J. Amer. Water Wks Ass.</i>	Journal of the American Water Works Association
<i>J. appl. Bact.</i>	Journal of Applied Bacteriology
<i>J. appl. Chem.</i>	Journal of Applied Chemistry
<i>J. appl. Phys.</i>	Journal of Applied Physiology

<i>J. Ass. off. agric. Chem.</i>	Journal of the Association of Official Agricultural Chemists
<i>J. Bact.</i>	Journal of Bacteriology
<i>J. biol. Chem.</i>	Journal of Biological Chemistry
<i>J. cell. comp. Physiol.</i>	Journal of Cellular and Comparative Physiology
<i>J. chem. Soc.</i>	Journal of the Chemical Society
<i>J. clin. Path.</i>	Journal of Clinical Pathology
<i>J. Dairy Res.</i>	Journal of Dairy Research
<i>J. Dairy Sci.</i>	Journal of Dairy Science
<i>J. exp. Med.</i>	Journal of Experimental Medicine
<i>J. gen. Microbiol.</i>	Journal of General Microbiology
<i>J. gen. Physiol.</i>	Journal of General Physiology
<i>J. Hyg., Camb.</i>	Journal of Hygiene
<i>J. Immunol.</i>	Journal of Immunology
<i>J. ind. Hyg.</i>	Journal of Industrial Hygiene
<i>J. infect. Dis.</i>	Journal of Infectious Diseases
<i>J. Inst. chem. Engrs</i>	Journal of the Institution of Chemical Engineers
<i>J. Inst. Water Engrs</i>	Journal of the Institution of Water Engineers
<i>J. invest. Dermatol.</i>	Journal of Investigative Dermatology
<i>J. lab. clin. Med.</i>	Journal of Laboratory and Clinical Medicine
<i>J. Milk Tech.</i>	Journal of Milk (and Food) Technology
<i>J. Obstet. Gynaec. Brit. Emp.</i>	Journal of Obstetrics and Gynaecology of the British Empire
<i>J. Nutrit.</i>	Journal of Nutrition
<i>J. oil col. Chem. Ass.</i>	Journal of the Oil and Colour Chemists Association
<i>J. Path. Bact.</i>	Journal of Pathology and Bacteriology
<i>J. Pharm. Pharmacol.</i>	Journal of Pharmacy and Pharmacology
<i>J. pharm. Sci.</i>	Journal of Pharmaceutical Sciences
<i>J. Pharmacol.</i>	Journal of Pharmacology and Experimental Therapeutics
<i>J. phys. Chem.</i>	Journal of Physical Chemistry
<i>J. roy. san. Inst.</i>	Journal of the Royal Sanitary Institute
<i>J. Sci. Food Agric.</i>	Journal of the Science of Food and Agriculture
<i>J. Text. Inst.</i>	Journal of the Textile Institute, Manchester
<i>Lancet</i>	The Lancet
<i>Med. norsk farm. Selsk.</i>	Meddelelser fra Norsk farmaceutisk Selskap
<i>Mich. State Coll. Tech. Bull.</i>	Michigan State College Technical Bulletin
<i>Agr.</i>	Agriculture
<i>Milchwiss.</i>	Milchwissenschaft
<i>Nature, Lond.</i>	Nature
<i>Nord. hyg. Tids.</i>	Nordisk hygienisk Tidsskrift
<i>Nucleonics</i>	Nucleonics
<i>Pharm. Acta Helv.</i>	Pharmaceutica Acta Helvetiae
<i>Pharm. J.</i>	Pharmaceutical Journal
<i>Pharm. Monat.</i>	Pharmazeutische Monatshefte
<i>Phil. Mag.</i>	Philosophical Magazine
<i>Physiol. Rev.</i>	Physiological Reviews
<i>Phytopath.</i>	Phytopathology

<i>Phytopath. Z.</i>	Phytopathologische Zeitschrift
<i>Practitioner</i>	The Practitioner
<i>Proc. nat. Acad. Sci.</i>	Proceedings of the National Academy of Sciences, Washington
<i>Proc. Roy. Soc.</i>	Proceedings of the Royal Society
<i>Proc. roy. Soc. Med.</i>	Proceedings of the Royal Society of Medicine
<i>Proc. Soc. agric. Bact.</i>	Proceedings of the Society of Agricultural Bacteriologists
<i>Proc. Soc. appl. Bact.</i>	Proceedings of the Society for Applied Bacteriology
<i>Proc. Soc. exp. Biol., N.Y.</i>	Proceedings of the Society for Experimental Biology and Medicine
<i>Publ. Hlth Rep., Wash.</i>	Public Health Reports
<i>Quart. J. Pharm.</i>	Quarterly Journal of Pharmacy and Pharmacology
<i>Radiology</i>	Radiology
<i>Rad. Res.</i>	Radiation Research
<i>Research, Lond.</i>	Research
<i>Rev. sci. Inst.</i>	Review of Scientific Instruments
<i>Science</i>	Science
<i>Soap</i>	Soap and Sanitary Chemicals <i>later</i> Soap and Chemical Specialities
<i>Soap, Perf. Cosm.</i>	Soap, Perfumery and Cosmetics
<i>Surgery</i>	Surgery
<i>Surg. Gynec. Obstet.</i>	Surgery, Gynecology and Obstetrics
<i>Trans. Faraday Soc.</i>	Transactions of the Faraday Society
<i>Trans. Inst. chem. Engrs, Lond.</i>	Transactions of the Institution of Chemical Engineers
<i>Tubercle</i>	Tubercle
<i>U.S. publ. Hlth Rep.</i>	United States Public Health Report
<i>Vet. Rec.</i>	Veterinary Record
<i>Virology</i>	Virology
<i>Yokohama Med. Bull.</i>	Yokohama Medical Bulletin
<i>Zent. Bakt.</i>	Zentralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten
<i>Z. ges. Hyg.</i>	Zeitschrift für die gesamte Hygiene und ihre Grenzgebiete
<i>Z. Hyg. InfektKr.</i>	Zeitschrift für Hygiene und Infektionskrankheiten
<i>Z. physiol. Chem.</i>	Hoppe-Seyler's Zeitschrift für physiologische Chemie

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PART II

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Triphenylmethane dyes: mode of action - relationship between constitution and activity; uses and activities of the medicinal dyes. The acridines; mode of action - mechanism of bacteriostasis, significance of ionization, 'dimensional factor', effect of substituent radicals, resistance; some useful acridines and their activities; uses of acridines.

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Quaternary ammonium compounds: chemical and physical properties, constitution and activity; mechanism of antibacterial activity; range of antimicrobial activities - selective action, sporicidal activity, antifungal activity, antiviral activity, toxicity; factors affecting antibacterial activities - organic matter, adsorption phenomena, compatibilities and incompatibilities; testing quaternary ammonium compounds - inactivating and antidotal substances, specific test methods; uses of quaternaries - in surgery and medicine, in the food industries, in dairying. The amphoteric compounds - germicidal activities, uses.

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Chlorine: active compounds of chlorine - hypochlorites, the inorganic chloramines, the organic chlorine-releasing compounds; available chlorine; the disinfecting action of chlorine - mechanism of disinfection, effect of pH value, effect of concentration, effect of temperature, effect of organic matter, effect of ammonia and amino compounds; chlorine disinfection in practice - water treatment, in swimming baths, in sewage, in dairying, for food and drinking utensils, in medicine. Iodine: general properties; germicidal properties - activity against bacteria, effect of concentration, effect of organic matter, effect of pH value, activity against spores, against viruses, against fungi; compounds of iodine - iodoform, iodine trichloride, iodonium compounds, iodophores, other compounds; iodine disinfection in practice - in skin disinfection, for surgical and domestic equipment, in dairying, in water treatment.

16 HEAVY METALS 411

Mercury compounds: mode of action, action on spores; activity of mercury compounds - inorganic compounds, organic compounds; uses of the mercurials. Silver and its compounds: oligodynamic silver - mode of action, activities and uses; silver salts - soluble salts, colloidal silver preparations. Copper compounds. Tin compounds. Other metal salts.

PART VI

Preservation and Preservatives

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General principles. Preservation by physical means: foods and food products - pasteurization, dehydration, packaging and storage conditions, osmosis, acidity, radiation treatment; industrial materials - humidity. Preservation with chemicals: foods; industrial materials - textiles, wood, paper and board, paints, leather, other industrial materials; pharmaceutical and cosmetic preparations - preparations administered parenterally, ophthalmic preparations, preparations for external or oral use.

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