Textbook of Microbiology

Sixth Edition

The sixth edition of *Textbook of Microbiology* is thoroughly revised and updated which aims to keep pace with the rapidly increasing information in medical sciences. A chapter on automation in microbiology has been added. Zika virus has been described in chapter of arboviruses. The text is presented in simple and lucid manner. It is illustrated with coloured and computer-drawn figures, clinical photographs and photomicrographs. These make the book colourful and readers can have better understanding of the biology of microorganisms. Each chapter ends with key facts, and essay type, short answer type and multiple choice questions. The former summarizes the whole chapter, and the latter help the student to know the type of questions asked in the examination. Overview of microbiology in the last chapter summarizes the whole book. The book is user-friendly, easy to understand, and will be highly useful to MBBS, BDS, MSc and MD microbiology students.

D R Arora, MD, PhD, MNAMS, Ex-Professor and Head, Department of Microbiology, Postgraduate Institute of Medical Sciences, Rohtak, Haryana; and Maharaja Agarsen Medical College, Agroha, Haryana; Ex-Professor and Head, Department of Microbiology, Medical Superintendent, and Dean, Faculty of Allied Health Sciences, SGT University, Gurugram, Haryana; Lead Assessor and Member, Accreditation Committee, National Accreditation Board for Testing and Calibration Laboratories (NABL), Gurugram, Haryana; Principal Assessor, National Accreditation Board for Hospitals & Healthcare Providers (NABH), New Delhi; Assessor, National Accreditation Board for Education and Training (NABET), New Delhi, has more than 43 years of teaching experience in microbiology to medical and dental undergraduate and postgraduate students. Besides conducting and supervising research in microbiology, he has published nine textbooks on microbiology, parasitology and mycology, and 150 research articles in several indexed national and international journals of repute. The results of his research on malaria parasites and *Klebsiella pneumoniae* have been cited in World Health Organization WHO/MAL/8310003 and *Topley & Wilson's Microbiology and Microbial Infections, Bacteriology*, Vol 2, 10th edn, 2005, respectively. He has supervised a number of PG students of PhD, MD and MS in appreciation of outstanding research carried out by him in India on bacteriocins of *Klebsiella pneumoniae*, he was awarded Smt. Kunti Mehrotra Award of Indian Association of Pathologists and Microbiologists in 1983. In recognition of significant contribution to the advancement of medical sciences, he was elected Member of National Academy of Medical Sciences, India in 1985. He has been a Visiting Professor at University of Mauritius in 1989. He was awarded WHO fellowship on Laboratory Aspects of HIV/AIDS and STD at Community Health Surveillance and Laboratories Administration, Baltimore, Maryland, USA in 1992. He was honoured by Indian Medical Association, Kaithal, Haryana on the eve of Doctors' Day on 01.07.1999. He has been examiner for BDS, MBBS, MD, DNB and PhD microbiology of a number of universities. His biography including academic activities and research work has been published in *Who's Who in Medicine and Healthcare* 2011–12 (8th edn), NJ 07922, USA, distinguishing him as one of the leading healthcare professionals from around the world.

Brij Bala Arora, MD, Ex-Senior Professor and Head, Department of Pathology, Postgraduate Institute of Medical Sciences, Rohtak, Haryana; Ex-Director-Principal and Senior Professor and Head, Department of Pathology, SGT Medical College, Gurugram, Haryana, had more than 42 years of teaching experience in pathology to medical, dental and nursing undergraduate and postgraduate students. She had published five textbooks, and 175 research articles in several indexed national and international journals of repute. Her research on AgNOR staining technique received international importance and paper on morphometric analysis of AgNOR in lymph node lesions was published in "Advances in Clinical Pathology 6:95-99, 2002". She had supervised 67 PG students of PhD, MD, MS, MDS and DNB. She had been examiner for BSc Nursing, BDS, MBBS, MD, DNB and PhD of a number of universities. She had been conferred MAMCOS scroll of honour in VIII Annual Conference on 20th December 1994 at Maulana Azad Medical College, New Delhi; Bharat Jyoti Award for outstanding services, achievements and contributions on 23rd June 2006 at New Delhi and International Gold Star Award 2010 for outstanding achievements at 25th Indo-Thai Entrepreneurs Summit on 27th August, 2010 at Bangkok, Thailand. Her biography including academic activities and research work has been published in *Who's Who in Medicine and Healthcare* 2011–12 (8th edn), NJ 07922, USA, distinguishing her as one of the leading healthcare professionals from around the world. She had also been conferred Lifetime Achievement Award in recognition of outstanding achievements at 33rd National Seminar on December 4th, 2012, New Delhi at Indian Achievers Forum.

Dedicated to Education

CBS

CBS Publishers & Distributors Pvt Ltd

4819/XI, Prahlad Street, 24 Ansari Road, Daryaganj, New Delhi 110 002, India

E-mail: delhi@cbspd.com, cbspubs@airtelmail.in; Website: www.cbspd.com

New Delhi | Bengaluru | Chennai | Kochi | Kolkata | Mumbai

Bhopal | Bhubaneswar | Hyderabad | Jharkhand | Nagpur | Patna | Pune | Uttarakhand | Dhaka (Bangladesh) | Kathmandu (Nepal)

QR code to access online CBS Catalogue

ISBN: 978-93-89565-93-5

Sixth Edition

Textbook of Microbiology

Arora

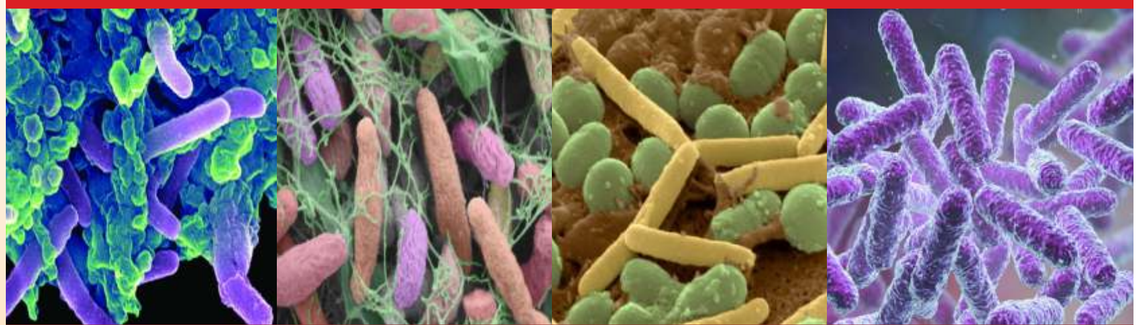
Arora

CBS

Sixth Edition

Textbook of Microbiology

Revised and updated as per the latest Competency Based Undergraduate Curriculum for the Indian Medical Graduate prescribed by Medical Council of India (restructured as National Medical Commission)



D R Arora

Brij Bala Arora

CBS Dedicated to Education

CBS Publishers & Distributors Pvt Ltd

Sixth Edition

Textbook of Microbiology

Revised and updated as per the latest Competency Based Undergraduate Curriculum for the Indian Medical Graduate prescribed by Medical Council of India (restructured as National Medical Commission)

Other Books by D R Arora

- *Textbook of Microbiology for Dental Students*, 4th ed
- *Medical Parasitology*, 5th ed
- *Medical Mycology*, 2nd ed
- *Microbiology for Nursing & Allied Sciences*, 2nd ed
- *Practical Microbiology*, 2nd ed
- *Practical Microbiology for Dental Students*
- *Exam-Oriented Microbiology (Questions & Answers)*
- *Essentials of Microbiology for BSc Nursing Students*
- *MCQs in Microbiology and Parasitology (with Explanations)*
- *Microbiology for Medical Laboratory Technology Students*

Sixth Edition

Textbook of Microbiology

D R Arora MD PhD MNAMS

Ex-Professor and Head, Department of Microbiology,
Postgraduate Institute of Medical Sciences, Rohtak, Haryana, and
Maharaja Agarsen Medical College, Agroha, Haryana

Ex-Professor and Head, Department of Microbiology,
Medical Superintendent and Dean, Faculty of Allied Health Sciences,
SGT University, Gurugram, Haryana

Ex-WHO Fellow and Visiting Professor, University of Mauritius

Lead Assessor and Member, Accreditation Committee,
National Accreditation Board for Testing and Calibration Laboratories (NABL),
Gurugram, Haryana

Principal Assessor, National Accreditation Board for Hospitals and
Healthcare Providers (NABH), New Delhi

Assessor, National Accreditation Board for
Education and Training (NABET), New Delhi

Late Brij Bala Arora MD

Ex-Senior Professor and Head, Department of Pathology,
Postgraduate Institute of Medical Sciences, Rohtak, Haryana

Ex-Director-Principal and Senior Professor and Head,
Department of Pathology, SGT Medical College, Budhera,
Gurugram, Haryana

CBS

CBS Publishers & Distributors Pvt Ltd

New Delhi • Bengaluru • Chennai • Kochi • Kolkata • Mumbai

Bhopal • Bhubaneswar • Hyderabad • Jharkhand • Nagpur • Patna • Pune
• Uttarakhand • Dhaka (Bangladesh) • Kathmandu (Nepal)

Disclaimer

Science and technology are constantly changing fields. New research and experience broaden the scope of information and knowledge. The authors have tried their best in giving information available to them while preparing the material for this book. Although, all efforts have been made to ensure optimum accuracy of the material, yet it is quite possible some errors might have been left uncorrected. The publisher, the printer and the authors will not be held responsible for any inadvertent errors, or inaccuracies.

ISBN: 978-93-89565-93-5

Sixth Edition: 2020
First Edition: 1999
Reprint: 2001, 2002
Second Edition: 2003
Reprint: 2004, 2006
Third Edition: 2008
Reprint: 2008, 2011
Fourth Edition: 2012
Fifth Edition: 2017
Reprint: 2017

Published by Satish Kumar Jain and produced by Varun Jain for

CBS Publishers & Distributors Pvt Ltd
4819/XI Prahlad Street, 24 Ansari Road, Daryaganj, New Delhi 110 002, India
Ph: 011-23289259, 23266861, 23266867 Website: www.cbspd.com
Fax: 011-23243014 e-mail: delhi@cbspd.com; cbspubs@airtelmail.in

Corporate Office: 204 FIE, Industrial Area, Patparganj, Delhi 110 092
Ph: 011-49344934 Fax: 011-49344935 e-mail: publishing@cbspd.com; publicity@cbspd.com

Branches

- **Bengaluru:** Seema House 2975, 17th Cross, K.R. Road, Banasankari 2nd Stage, Bengaluru 560 070, Karnataka
  Ph: +91-80-26771678/79 Fax: +91-80-26771680 e-mail: bangalore@cbspd.com
- **Chennai:** 7, Subbaraya Street, Shenoy Nagar, Chennai 600 030, Tamil Nadu
  Ph: +91-44-26680620, 26681266 Fax: +91-44-42032115 e-mail: chennai@cbspd.com
- **Kochi:** 68/1534, 35, 36, Power House Road, Opposite KSEB, Kochi 682018, Kerala
  Ph: +91-484-4059061-65 Fax: +91-484-4059065 e-mail: kochi@cbspd.com
- **Kolkata:** 6/B, Ground Floor, Rameswar Shaw Road, Kolkata-700 014, West Bengal
  Ph: +91-33-22891126, 22891127, 22891128 e-mail: kolkata@cbspd.com
- **Mumbai:** 83-C, Dr E Moses Road, Worli, Mumbai-400018, Maharashtra
  Ph: +91-22-24902340/41 Fax: +91-22-24902342 e-mail: mumbai@cbspd.com

Representatives

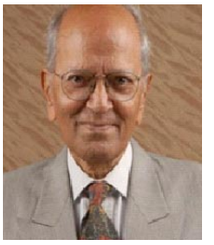
• **Bhopal**	0-8319310552	• **Bhubaneswar**	0-9911037372	• **Hyderabad**	0-9885175004	• **Jharkhand**	0-9811541605
• **Nagpur**	0-9421945513	• **Patna**	0-9334159340	• **Pune**	0-9623451994	• **Uttarakhand**	0-9716462459
• **Dhaka (Bangladesh)**	01912-003485	• **Kathmandu (Nepal)**	977-9818742655				

Printed at: Goyal Offset Printers, GT Karnal Road, Industrial Area, Delhi, India

Dedicated to the Sweet Memories of
Our Loving Daughter,
Dr Hina Arora

Dr Hina Arora
BDS, IDES 2001
09·04·1976 to 02·11·2009

Foreword



Infectious diseases account for 26% of the total deaths in the world and this percentage is much higher in the developing world including India. A sound knowledge of the microbes that cause these diseases is vital in the understanding of their epidemiology, pathogenesis, diagnosis, management and prevention. The emergence of new microbes and the diseases caused by them due to changing environment and ecology is a challenge. The persistent problem of hospital-acquired infections in ever-increasing population of immunosuppressed patients nowadays and the difficulty of their management due to antimicrobial drug resistance and non-availability of new anti-infective molecules is a problem faced by the medical community. Microbiology is central to these challenges. India needs many more microbiologists and also needs to increase its diagnostic facilities.

The sixth edition of this book is an updated version of the previous one and elegantly meets the new requirements. Laboratory diagnosis of various microbial infections has been simplified with the help of flowcharts. The principal author, Dr D R Arora, is an accomplished undergraduate and postgraduate teacher and has mastered the art of interaction and communication for decades for the needs of the students. Late Dr Brij Bala Arora, the coauthor, has added the component of pathological basis of infectious diseases. The latest national and international references at the end of each chapter are provocative for the inquisitive minds. Each chapter has relevant, essay-type, short answer and multiple choice questions for quick references and prepares the examinees for future written and oral examinations.

This book will be useful for the students, teachers and practitioners of not only microbiology but also of family medicine and also those interested in infectious diseases. I strongly recommend the book to them as a daily and ready reckoner.

I wish to compliment the authors for doing an excellent job.

T D Chugh
National Emeritus Professor
National Academy of Medical Sciences (India)

Preface to the Sixth Edition

Human history is full of examples of major devastations caused by bacteria and viruses. Some of these historically important diseases still occur such as tuberculosis and yellow fever. Microorganisms are always one step ahead of us. We develop means (an antibiotic/a vaccine) to control/eradicate the pathogenic microorganisms and they develop genes/mechanisms to resist these means. Microorganisms are evolving to cause new infectious diseases such as Lyme disease and AIDS. On the top of that, microorganisms are being used as weapons of war. Biotechnology and genetic engineering have added new dimension to the threat whereby scientists/terrorists can alter strains of bacteria to cause atypical symptoms, acute fatal disease, and increased transmissibility, and make microorganisms resistant to usual antibiotics. Our understanding of microbiology and immunology is rapidly expanding with new discoveries in all areas. In the future, study of space microbiology may help to reveal if there is life on other planets. I, as author and teacher, used my experience to choose the most important information for inclusion in this book.

Rapidly increasing information in medical science requires that textbooks be revised and updated to keep pace. Earlier editions of the *Textbook of Microbiology* have received an overwhelming response from undergraduate and postgraduate students, and the teachers. This has played a vital role in bringing out the sixth edition of the book. Each chapter has been carefully updated and expanded to include new medically relevant discoveries. The text has been thoroughly revised as per Medical Council of India Competency-based Undergraduate Curriculum for the Indian Medical Graduate. Laboratory diagnosis of various microbial infections has been simplified with the help of flowcharts. A chapter on automation in microbiology has been added. Zika virus has been described in the chapter of arboviruses. Unnecessary details have been removed. The text is presented in a simple and lucid manner. It is illustrated with coloured and computer-drawn figures, and clinical photographs and photomicrographs. These make the book colourful and the readers can have a better understanding of the biology of microorganisms. New illustrations have been added at various places for better understanding. The book is divided into seven sections: General Bacteriology; Systemic Bacteriology; Virology; Medical Mycology; Clinical Microbiology; Bacteriology of Water, Milk and Air, and Biological Warfare; and Quality Assurance, Ethics and Overview of Microbiology. For quick review and recapitulation, key facts and multiple choice questions have been given at the end of each chapter. In order to help the students perform better in the examination, the competencies expected from the students after reading various chapters, have been given in the beginning of the chapters.

I am thankful to many students and professional colleagues who have offered their advice and constructive criticism throughout the development of sixth edition of the book. I am deeply indebted to Dr Seema Gupta MD, Professor of Pharmacology, Government Medical College, Jammu (J&K), for contributing a chapter on chemotherapy. I am also thankful to Dr PS Gill, Professor of Microbiology, Postgraduate Institute of Medical Sciences, Rohtak, for drawing the figures. I am grateful for valuable professional help and support provided by Mr YN Arjuna (Senior Vice President—Publishing, Editorial and Publicity), Ms Ritu Chawla (General Manager—Production), Mr BM Singh and other staff at CBS Publishers & Distributors Pvt Ltd. I honestly acknowledge the most sincere and dedicated support and advice of Mr Dharmvir. Thanks are also due to Mr Neeraj Sharma for thorough and careful proofreading.

This book will be highly useful to MBBS, BDS, MSc and MD microbiology students. It is also hoped that it will serve as a useful resource for teachers of microbiology and other specialities including infectious diseases. The readers are requested to send their suggestions for the improvement of the book which will be incorporated in the subsequent editions. Shortcomings, if any, may please be communicated at drararadr@rediffmail.com.

D R Arora

Preface to the First Edition

A majority of the patients seeking medical advice are suffering from some sort of infectious disease and more than one-third of total deaths in the world are associated with microbial diseases. Millions of infants die of bacterial, viral and protozoal infections, and antimicrobial drug resistance and hospital-associated infections are causing considerable alarm. The re-emergence of infectious diseases, thought to be well under control in large parts of the world, and emergence of new infections with high case fatality rates and the potential of their rapid spread have led the WHO to issue a wake up call. The eradication of smallpox and effective control of many communicable diseases has led to a false sense of security and complacency in many countries.

New agents of infectious diseases continue to be recognized. The most notorious of these is undoubtedly the human immunodeficiency virus, the causative agent of acquired immunodeficiency syndrome. It was identified in 1983. The outbreaks of plague in 1994, cholera in 1995, and dengue haemorrhagic fever in 1996, among many others, have highlighted the urgency for strengthening the disease surveillance system so that early warning signals are recognized and appropriate control measures are initiated in a timely manner.

Microbiologists face many new species, genera and families of microorganisms and some of them have been re-assigned to these. The methods of laboratory diagnosis of infectious diseases and vaccine production have been revolutionized with the development of recombinant DNA technology, polymerase chain reaction, nucleic acid probes, radioimmunoassay, enzyme-linked immunosorbent assay, etc. Therefore, a thorough knowledge of microbiology is essential to every healthcare worker. This book gives all the essential details of general microbiology, description of various microorganisms, i.e. morphology, cultural characteristics, antigenic structure, toxin production, pathogenesis, immunity, epidemiology, laboratory diagnosis, prevention and treatment.

There is a well-known saying, “prevention is better than cure”, therefore, methods of prevention of each infectious disease including vaccines have been described. However, if disease has established then an early and accurate diagnosis is essential. The same has been described in proper details giving all latest methods of diagnosis.

D R Arora

Index of Competencies

Competency-based Undergraduate Curriculum for the Indian Medical Graduate

MI5.2	Describe the etiopathogenesis, clinical course and discuss the laboratory diagnosis of encephalitis.	414, 429, 455
MI5.3	Identify the microbial agents causing meningitis.	183, 189, 319, 328, 414, 429, 455, 542
MI6.1	Describe the etiopathogenesis, laboratory diagnosis and prevention of infections of upper and lower respiratory tract.	28, 542
MI6.2	Identify the common etiologic agents of upper respiratory tract infections (Gram staining).	28, 163, 183, 542
MI6.3	Identify the common etiologic agents of lower respiratory tract infections (Gram stain and Ziehl-Neelsen stain).	28, 183, 542
MI7.1	Describe the etiopathogenesis and discuss laboratory diagnosis of infections of genitourinary system.	28, 542
MI7.2	Describe the etiopathogenesis and discuss the laboratory diagnosis of sexually transmitted infections. Describe the preventive measures.	28, 542
MI7.3	Describe the etiopathogenesis, clinical features, the appropriate method for specimen collection, and discuss the laboratory diagnosis of urinary tract infections.	163, 172, 189, 223, 267, 279, 314, 319, 344, 542
MI8.1	Enumerate the microbial agents and their vectors causing zoonotic diseases. Describe the morphology, mode of transmission, pathogenesis and discuss the clinical course, laboratory diagnosis and prevention.	72, 298, 435
MI8.2	Describe the etiopathogenesis of opportunistic infections (OI) and discuss the factors contributing to the occurrence of OI, and the laboratory diagnosis.	469
MI8.3	Describe the role of oncogenic viruses in the evolution of virus-associated malignancy.	492
MI8.4	Describe etiologic agents of emerging infectious diseases. Discuss the clinical course and diagnosis.	539
MI8.5	Define healthcare-associated infections (HAI) and enumerate the types. Discuss the factors that contribute to the development of HAI and the methods for prevention.	469
MI8.6	Describe the basics of infection control.	550
MI8.7	Demonstrate infection control practices and use of personal protective equipment (PPE).	550
MI8.8	Describe the methods used and significance of assessing the microbial contamination of food, water and air.	565
MI8.9	Discuss the appropriate method of collection of specimen in the performance of laboratory tests in the detection of microbial agents causing infectious disease.	28
MI8.11	Demonstrate respect for patient samples sent to the laboratory for performance of laboratory tests in the detection of microbial agents causing infectious disease.	587
MI8.12	Discuss confidentiality pertaining to patient identity in laboratory results.	581
MI8.13	Discuss the appropriate laboratory test in the diagnosis of the infectious disease.	581
MI8.14	Demonstrate confidentiality pertaining to patient identity in laboratory results.	587
MI8.15	Choose and interpret the results of the laboratory tests used in diagnosis of infectious disease.	581
MI8.16	Describe the National Health Programmes in the prevention of common infectious diseases.	560
BI10.5	Describe antigens and concept involved in vaccine development.	79, 87
PA7.5	Describe the immunology and the immune response to cancer.	150
PA9.1	Describe the principles and mechanisms involved in immunity.	117
PA9.2	Describe the mechanisms of hypersensitivity reactions.	137
PA9.3	Describe the HLA system and the immune principles involved in transplant and mechanisms of transplant rejection.	150
PA9.6	Define and describe the pathogenesis and pathology of HIV and AIDS.	469
PA10.3	Define and describe the pathogenesis and pathology of leprosy.	239
PA22.5	Enumerate and describe infections transmitted by blood transfusion.	156
PA26.4	Define and describe the etiology, types, pathogenesis, stages, morphology microscopic appearance and complications of tuberculosis.	223
PA35.1	Describe the etiology, pathogenesis, differentiating factors and CSF findings in meningitis.	542
PH1.43	Describe and discuss the rational use of antimicrobials including antibiotic stewardship programme.	550
PH1.45	Describe the drugs used in multidrug-resistant tuberculosis (MDR-TB) and extensively drug-resistant tuberculosis (XDR-TB).	223
CM3.3	Describe the etiology and basis of water-borne diseases.	565
CM3.6	Describe the role of vectors in the causation of diseases.	72
CM14.1	Define and classify hospital waste.	38
CM14.2	Describe various methods of treatment of hospital waste.	38
CM14.3	Describe laws related to hospital waste management.	38
DR7.1	Describe the etiology, microbiology, pathogenesis, clinical presentations and diagnostic features of dermatophytes.	503
DR7.2	Identify *Candida* species in fungal scrapings and KOH mount.	503
DR9.1	Classify, describe the epidemiology, microbiology, pathogenesis, clinical presentations and diagnostic features of leprosy.	239

Contents

Section 2: Systemic Bacteriology

Section 3: Virology