Notes on Medical Bacteriology

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FOREWORD BY

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Foreword

These admirable notes represent an entirely successful effort to present the main facts of medical microbiology in the fewest possible words. They will surely come as a boon and a blessing to all students who require an introduction to the subject which picks out the information that matters most from the now embarrassingly large volume of good published work. This mass of riches makes the work of authors of supposedly elementary textbooks very difficult indeed. The essence of art is selection, but the selection must be properly balanced, and therein lies the difficulty. In teaching medical microbiology to medical undergraduates, to young medical graduates who are beginning to specialise in the subject, and to science graduates and scientific officers who are to work in medical laboratories, it is important to give as an introduction enough about the biology of the microbes to make clear how they may be identified so that the correct specimens are sent for examination, the correct methods used to that end, and the correct interpretations put upon the laboratory findings. Matters of detail and method soon become second nature to experienced microbiologists in their day-to-day work; but the new student must not be put off the subject by thinking that he must memorise from the beginning all the details in the cookery book of the microbiologists' kitchen. What these notes do so well is to set out the necessary basic facts and principles clearly and briefly for noting and easy reference, and then to concentrate on the exciting facts about where microbes live, how they get around, how they may be contained, what diseases they produce, and how these diseases may be prevented or treated. The concerns both of individual patients and of the community are kept in proportion. Immunisation, hygiene, epidemiology, and antimicrobial therapy are all competently dealt with alongside the facts about the microbes concerned. The result is a miniature that is also a masterpiece. I have pleasure in writing this foreword and in wishing the book the success I know it deserves.

J. W. H.

Preface

This book is intended primarily for medical students studying for the Professional Examination in Microbiology, but we hope it may also be useful for dental and nursing undergraduates. It has been written as a collaborative effort by the teaching staff of the Department of Bacteriology in the Royal Infirmary, Glasgow and aims to give a concise account of medical bacteriology. Systematic bacteriology is dealt with briefly and we have tried to emphasise the clinical aspects of the subject which seem to us of most importance in present-day medical practice. It should be supplemented by reading from a larger textbook and some recommended books for further reading are listed on page 344.

We thank many colleagues for advice and much useful discussion, notably Mr R. Brown, Professor J. G. Collee, Dr Heather M. Dick, Dr R. J. Fallon, Dr Eve Kirkwood, Dr M. Laidlaw, Mrs Janet McCabe, Dr G. Masterton, Dr D. Reid and Dr Jean Thomson. Professor K. Hodgkin allowed us to quote from his excellent book *Towards Earlier Diagnosis in Primary Care*. Thanks are also due to Professor J. Hume Adams, Dr R. St C. Barnetson, Professor W. Brumfitt, Dr R. S. Kennedy, Dr A. Lyell and Dr P. S. MacFarlane, who took a great deal of trouble to provide us with slides and photographs. We are grateful to Mr W. McCormick, for allowing us to reproduce some of the excellent slides he has prepared for the department over many years. We thank Mrs Alison Fletcher for typing the manuscript and Mrs Brenda Burns and Mr Ian McKie for preparing the drawings and photographs respectively. We would also express our thanks to Dr Valerie Inglis for compiling the index.

Both of us owe a particular debt to Sir James Howie not only for writing the foreword to the book but for our early years of training in his department. He inspired a whole generation of medical microbiologists.

Glasgow, 1981

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Dr D. J. Platt

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SECTION ONE

Bacterial biology

1

Introduction

Medical students need to learn bacteriology in order to diagnose and treat bacterial infections successfully.

Bacterial disease is still widespread and common: but its spectrum is changing so that once familiar diseases are now rare. Increasingly, the work of bacteriology laboratories is concerned with infection in patients in general hospitals — as distinct from fever hospitals — and in general practice.

The following are among the most important aspects of bacteriology which doctors must know in order to deal with infection.

Pathogenesis. The ways in which bacteria produce disease in the human body — essential information for diagnosis and treatment.

Diagnosis. Laboratory investigation depends on taking correct specimens and being able to assess the results obtained from the laboratory.

Treatment. Bacterial disease is one of the few conditions in medicine for which specific and highly effective therapy is available.

Epidemiology. The spread, distribution and prevalence of infection in the community.

Prevention. Many bacterial diseases have been virtually eradicated by immunization, public health measures and improved living standards.

HISTORY

Contagion. Since biblical times it has been known that some diseases spread from person to person.

The following are some of the pioneers responsible for the science of bacteriology as it is today.

Antony Van Leeuwenhook: a Dutch draper who made a microscope and in 1675 observed 'animalcules' in samples of water, soil and human material.

Louis Pasteur, the founder of modern microbiology: over a long period of brilliant and active research from 1860 to 1890, he developed methods of culture and showed that microorganisms cause disease. He also established the principles of immunisation.

Joseph Lister was Professor of Surgery in Glasgow Royal Infirmary. He applied Pasteur's observations to the prevention of wound sepsis — then almost an inevitable and often fatal complication of surgery. He discovered in 1867 an antiseptic technique to kill bacteria in wounds and in the air with carbolic acid. This revolutionised surgery.

Robert Koch was a German general practitioner who discovered the bacterial causes of many diseases — including tuberculosis in 1882. The discovery of agar as a setting agent for bacteriological media is attributed to Frau Koch from observations made in her kitchen. Koch defined the criteria for attributing an organism as the cause of a specific disease. These are the famous **Koch's postulates** and are as important today as when he propounded them:

1. The organism is found in all cases of the disease and its distribution in the body corresponds to that of the lesions observed.
2. The organism should be cultured outside the body in pure culture for several generations.
3. The organism should reproduce the disease in other susceptible animals.

   Nowadays a fourth postulate would be added:
4. Antibody to the organism should develop during the course of the disease.

Note. Many infectious diseases of which the cause is clearly identified do not fulfil the third and even occasionally the second of Koch's postulates.

Immunisation

The first successful immunisation was the demonstration by *Edward Jenner* in 1796 that a related but mild virus disease — cowpox — gave protection against subsequent attack by smallpox. Later, Pasteur's observations led to the development of the vaccines now widely and successfully used in medicine against diseases, e.g. diphtheria, tetanus, poliomyelitis, etc.

Antibiotics

The discovery of penicillin in 1929 by *Alexander Fleming* — a

Scot from Ayrshire — ushered in the antibiotic era. Generally derived from soil microorganisms, antibiotics kill or inhibit a wide variety of bacteria without harming their human host.

Public health

The development of a safe water supply, disposal of sewage, good housing and nutrition have also contributed largely to the decline in epidemic infectious disease.

2

Bacteria: organisation, structure, taxonomy

Bacteria are a heterogeneous group of unicellular organisms: their cellular organisation is described as *prokaryotic* (i.e. having a primitive nucleus) and differs from that of *eukaryotes* (plants, animals). Some of the main differences are listed in Table 2.1.

Table 2.1 Differences between prokaryotic and eukaryotic cells

Property	Prokaryotic cells	Eukaryotic cells
Chromosome number	One	Multiple
Nuclear membrane	Absent	Present
Mitochondria	Absent	Present

Genome. The most fundamental difference between bacteria and eukaryotes is that the bacterial chromosome, or genome, is a single circular molecule of double-stranded DNA; there is no nuclear membrane. Bacteria may from time to time harbour other smaller circular DNA molecules or plasmids which code for certain non-essential functions.

STRUCTURE

Bacteria have a rigid wall which determines their shape — only plants amongst other forms of living organisms possess this.

Shape. Bacteria may be:

1. Spherical — cocci
2. Cylindrical — bacilli
3. Helical — spirochaetes

Arrangement depends on the plane of successive cell divisions: e.g. chains — streptococci; clusters — staphylococci; diplococci — pneumococci; angled pairs or palisades — corynebacteria.

Gram's stain divides bacteria into Gram-positive or Gram-negative, an important step in classification. The Gram-staining reaction depends on the structure of the cell wall.

A diagram of a typical but composite bacterium is shown in Figure 2.1. Bacteria are cells with a rigid cell wall which surrounds the protoplast; this consists of a cytoplasmic membrane enclosing internal components and structures such as ribosomes and the bacterial chromosome.

External structures

External structures which protrude from the cell into the environment are present in many bacteria. These structures are:

1. *Flagella:* elongated filaments responsible for motility; composed of a protein 'flagellin' — chemically similar to myosin (Fig. 2.2).
2. *Pili:* finer shorter filaments extruding from the cytoplasmic membrane; also protein (pilin), they are responsible for adhesion (common pili) and probably for conjugation when genes are transferred from one bacterium to another (sex pili).

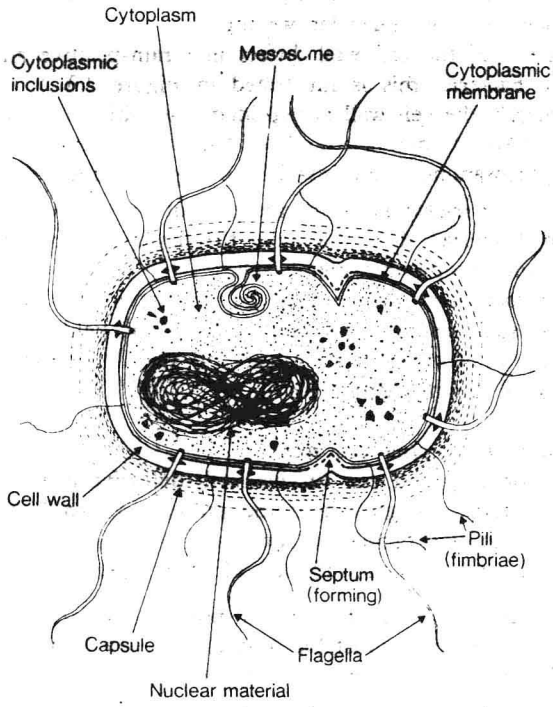

Fig. 2.1 Diagram of a typical but composite bacterial cell.

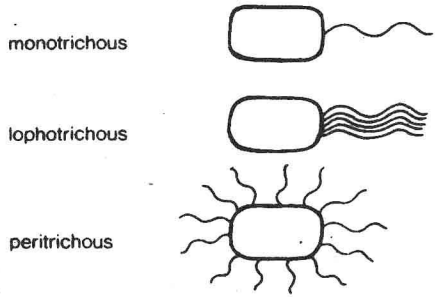

Fig. 2.2 Distribution of flagella on bacteria.

3. *Capsules:* amorphous material which surrounds many bacterial species as their outermost layer; usually polysaccharide, occasionally protein; often inhibit phagocytosis and so their presence correlates with virulence in certain bacteria.

Cell wall

In addition to conferring rigidity upon bacteria the cell wall also protects against osmotic damage. It is porous and permeable to substances of low molecular weight.

Structure of the cell wall differs in Gram-positive and Gram-negative bacteria; this is illustrated in Figure 2.3.

Chemically the cell wall is peptidoglycan: this is a mucopeptide composed of alternating strands of *N*-acetyl muramic acid and *N*-acetyl glucosamine cross-linked with peptide subunits (Fig. 2.4).

Teichoic or teichuronic acids are part of the cell wall of Gram-positive bacteria: they maintain the level of divalent cations outside the cytoplasmic membrane.

Other components which may be present in the cell wall are antigens such as the polysaccharide (Lancefield) and protein (Griffith) antigens of streptococci and the lipopolysaccharide O antigens of Gram-negative bacilli.

Bacteria with defective cell walls

Bacteria develop and can survive with defective cell walls: these can be induced by growth in the presence of antibiotics and a hyperosmotic environment to prevent lysis.

Bacteria without cell walls are of four types:

1. *Protoplasts:* derived from Gram-positive bacteria and totally lacking cell walls; unstable and osmotically fragile; produced artificially by lysozyme and hyperosmotic medium: require hyperosmotic conditions for maintenance.

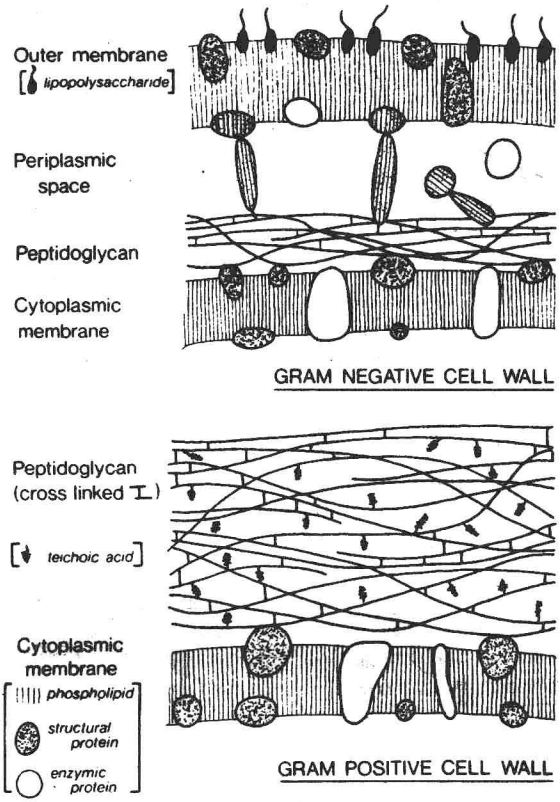

Fig. 2.3 Diagram showing the structure of Gram-negative and Gram-positive bacterial cell walls.

2. *Spheroplasts:* derived from Gram-negative bacteria; retain some residual but non-functional cell wall material; osmotically fragile; produced by growth with penicillin and must be maintained in hyperosmotic medium.
3. *L-forms:* cell wall-deficient forms of bacteria usually produced in the laboratory but sometimes spontaneously formed in the body of patients treated with penicillin; more stable than protoplasts or spheroplasts, they can replicate on ordinary media.
4. *Mycoplasma:* an independent bacterial genus of naturally occurring bacteria which lack cell walls; also stable and do not require hyperosmotic conditions for maintenance.