CRC

HANDBOOK
of
MICROBIOLOGY

Volume I
Organismic Microbiology

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PREFACE

Microbiology is a tree with many branches. The work of a Microbiologist may touch faraway fields and the diversity of information needed is great. It has thus been impossible to bind the pages of the *CRC Handbook of Microbiology* within a single cover. This first volume of the *Handbook of Microbiology* contains information dealing with microorganisms themselves. With the dedicated assistance of our Advisory Board and Contributors, the Editors have assembled information on various groups of microorganisms: bacteria, fungi, algae, protozoa, and viruses. In addition, information of a general nature is included, and also information that is most likely to be valuable to those interested in the organismic aspects of microbiology.

The guidelines given the authors by the Editors were very few. They were asked only to be as brief as possible, consistent with giving meaningful information, and to present their data, as much as practicable, in the form of tables. As a result, there is a lack of uniformity from one presentation to another. The Editors feel that there is virtue in this diversity, especially for the first edition of such a handbook. Experience will show us which type of presentation is most useful, and an attempt at more uniformity might be desirable in future editions. For this, the Editors must depend on the users of the Handbook, and all constructive comments, suggestions, and criticisms will be highly appreciated.

The Editors thank the Advisory Board and all the authors for their unselfish labors and express their gratitude to Mrs. Lisbeth Hammer for her excellent editorial work and to Mrs. Verna Lepping for the accuracy and intelligence of her secretarial assistance.

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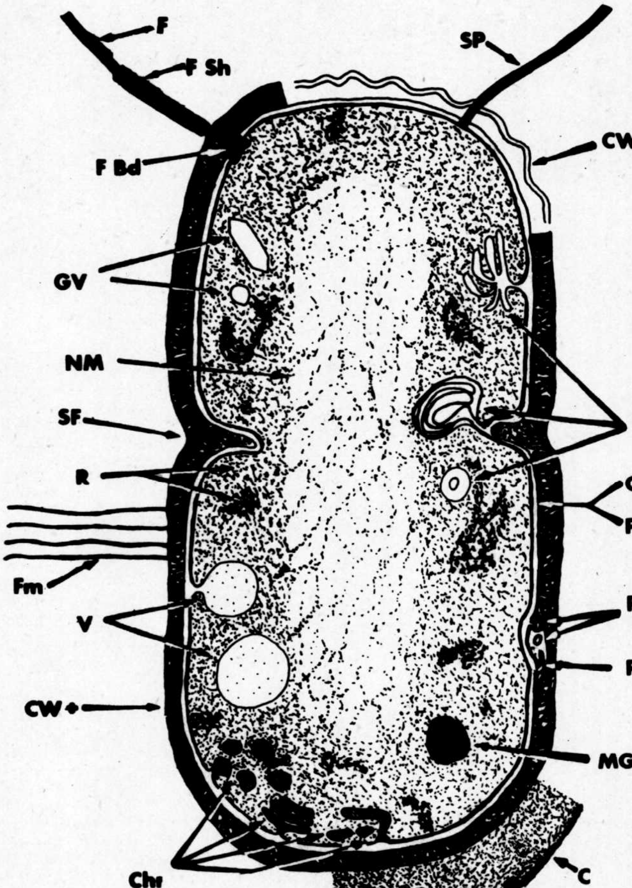
BACTERIA

INTRODUCTION TO THE BACTERIA

DR. HUBERT LECHEVALIER

Bacteria are procaryotic organisms that, if photosynthetic, do not produce oxygen. Most bacteria are quite small, being rods, cocci or filaments that range from 0.5 to 1 μm in diameter. Since the resolution of the light microscope is of the order of 0.2 to 0.3 μm, it is easily understandable that no great progress was made in the cytology of bacteria before the introduction of the electron microscope and the development of allied methods of shadowing, thin-sectioning and staining.[1-3]

The following diagram is an attempt at schematically illustrating the various cytological features that can be recognized in bacteria. Of course, no single bacterium harbors all the features illustrated. Actual micrographs of most morphological features illustrated in the diagram can be found in the *Pictorial Atlas of Pathogenic Microorganisms,* edited by G. Henneberg.[4]



C = capsule
Chr = chromatophores
CM = cytoplasmic membrane
CW+ = cell wall of Gram-positive bacteria
CW– = cell wall as in some Gram-negative bacteria
F = flagellum
FBd = flagellar basal body
Fm = fimbriae
FSh = flagellar sheath
GV = gas vacuoles
M = mesosome
MG = metachromatic granule
NM = nuclear material
PM = plasma membrane = CM
PT = periplasmic tubules
PV = periplasmic vesicles
R = ribosomes and polysomes
SF = septum formation
SP = sex pilus
V = vacuoles, probably containing reserve material

There is no rational order for presenting bacteria. Thus, the order that we have chosen is entirely empirical; the section starts with autotrophic bacteria and ends with heterotrophic rods and cocci not covered under other subdivisions.

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CHEMOAUTOTROPHIC BACTERIA

DR. CORINNE JOHNSON AND DR. WOLF VISHNIAC

Chemoautotrophic bacteria possess the ability to grow by oxidation of inorganic compounds, fixing carbon dioxide as a sole source of carbon. A precise definition of this group has eluded microbiologists; an attempt to classify autotrophs by physiological criteria has been presented by Kelly.[27]

Chemoautotrophic bacteria may be conveniently divided into three groups: the hydrogen bacteria, the sulfur-oxidizing bacteria, and the nitrifying bacteria. The majority of the members of these three groups are aerobes; some species are able to reduce nitrate instead of O_2 and are facultative anaerobes; a few are obligate anaerobes, reducing CO_2. Most of the organisms are Gram-negative, but the occurrence of Gram-positive hydrogen bacteria and of at least one Gram-positive sulfur bacterium suggests the occurrence of autotrophy beyond the limits of easily definable taxonomic boundaries. The autotrophs, to the extent that they have been studied in detail, fix CO_2 chiefly by the reactions of the Calvin cycle.

The autotrophs interact with other microorganisms that participate in the sulfur, nitrogen, and iron cycles in nature. These ecological interactions have been discussed by Alexander[6] and by Brock.[8]

THE HYDROGEN BACTERIA

All of the hydrogen-oxidizing bacteria are facultative heterotrophs and are versatile in utilizing carbon compounds for growth. It is thought that the universal facultative heterotrophy occurs because in hydrogen oxidation NAD^+ is reduced spontaneously, as in the oxidation of organic substrates by heterotrophs. Such reduction of NAD^+ is carried out either by a single enzyme (*Pseudomonas ruhlandii* and *P. saccharophila*) or, more commonly, by a two-step reaction. Specialized respiratory chains for the oxidation of inorganic compounds coupled to reverse electron transport phosphorylation, as found in the thiobacilli and nitrifying bacteria, are not required. A recent classification of the hydrogen bacteria[10,11] emphasizes the capacities of these organisms to grow on organic substrates and their similarities to heterotrophic organisms that possess similar nutritional capabilities.

There is no unity of cell type in the hydrogen bacteria. Included among them are Gram-negative rods with peritrichous flagellation, Gram-negative rods with polar flagellation, and Gram-negative cocci. Also included in this group are the methane bacteria, which are obligate anaerobes and for which CO_2 is the terminal electron acceptor. As suggested by the survey of Belyayeva,[7] one of the hydrogen bacteria was identified as an *Achromobacter* species.[38] While sulfate-reducing bacteria can utilize hydrogen as an electron donor, they do not couple this process to CO_2 fixation; hence they are excluded from this group because of their inability to grow autotrophically. A number of actinomycetes[15,44] have shown themselves to be facultative autotrophs. In addition, Eberhardt[12] has described an unnamed Gram-positive short rod capable of autotrophic growth with hydrogen, oxygen and carbon dioxide. This obligately aerobic, non-sporulating, non-motile yellow organism is of unknown taxonomic affiliation.

As the ability to oxidize molecular hydrogen is sometimes lost in cultures that are grown heterotrophically, it has been suggested[10,11] that hydrogen bacteria be classified with the heterotrophic species they resemble when grown on carbon substrates. One of the most interesting physiological problems of the hydrogen bacteria is the existence of mixotrophy, i.e., the simultaneous utilization of hydrogen and an organic substrate for growth (for example, fructose or lactate) with concomitant fixation of carbon dioxide. The control of the synthesis of hydrogenase and ribulose diphosphate carboxylase under varying conditions of mixotrophy and conversion from growth on hydrogen to growth on an organic substrate is a complex problem in metabolic control, which has been explored only in general terms. The subject has been discussed by Rittenberg;[37] a more general treatment of the enzymology of hydrogen oxidation has been presented by Peck.[35]

Characteristics of Hydrogen Bacteria[10,11,15,38]

Species	DNA Base Composition, moles % G+C	Inorganic Substrates	Terminal Electron Acceptor	Facultative Heterotrophy	Cell Type
Alcaligenes					
eutrophus	66.3–66.8	H_2	O_2, NO_3^-	+	Gram-negative rods, peritrichous flagella
paradoxus	68–70	H_2	O_2	+	Gram-negative rods, long, fragile, peritrichous flagella
Paracoccus					
denitrificans	66.3–66.8	H_2	O_2, NO_3^-	+	Gram-negative cocci, non-motile
Pseudomonas					
facilis	61.7–63.8	H_2	O_2	+	Gram-negative rods, polar flagella
flava	67.3	H_2	O_2	+	Gram-negative rods, polar flagella
palleronii	66.8	H_2	O_2	+	Gram-negative rods, polar flagella
ruhlandii		H_2	O_2	+	Gram-negative rods, polar flagella
saccharophila	68.9	H_2	O_2	+	Gram-negative rods, polar flagella
Methanobacterium					
soehngenii		H_2	CO_2	*a*	Gram-variable rods, non-motile
Methanococcus sp.		H_2	CO_2	*a*	Gram-variable cocci, non-motile
Methanosarcina sp.		H_2	CO_2	*a*	Gram-variable cocci in regular cubical packages, non-motile
Mycobacterium					
phlei 134[b]		H_2	O_2	+	Gram-positive rods, non-motile, rarely branching or filamentous, acid-fast
Nocardia					
saturnea 71[b]		H_2	O_2	+	Gram-positive rods, cocci, or branching mycelia, acid-fast