CRC Handbook of Microbiology

2nd Edition

Volume VII
Microbial Transformation

Editors

Allen I. Laskin

Hubert A. Lechevalier

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PREFACE

Microorganisms have been useful not only in synthesizing compounds which often dazzled the organic chemist by their complexity, but also by transforming preexisting or chemically synthesized compounds. These transformations were often of a type not easily performed by chemical methods. The enzymes of microorganisms have been able to reach molecular nooks and crannies and have been of tremendous assistance in the synthesis of novel organic compounds.

Microbial transformations occupied about 450 pages of Volume IV of the first edition of the *HANDBOOK OF MICROBIOLOGY*. Revisions and additions have enlarged the text to the point that the subject deserves a volume of its own.

We join the staff of CRC Press in extending our thanks to our authors, especially Dr. Claude Vézina and his collaborators, for contributing to this volume. We are all also greatly indebted to the members of our Advisory Board for their helpful guidance.

THE EDITORS

Allen I. Laskin, Head of Biosciences Research at Exxon Research and Engineering Company, Annandale, N.J., received his B.S. degree in Biology from the City College of New York in 1950. His M.A. and Ph.D. degrees in Microbiology were obtained from the University of Texas in 1952 and 1955, respectively.

From 1955 to 1969 Dr. Laskin was at the Squibb Institute for Medical Research, first as Senior Research Microbiologist, then as Head of Microbial Biochemistry, and subsequently as Assistant Director of Microbiology. His research on microbial transformations of steroids led to several publications and more than 20 U.S. patents. Dr. Laskin then switched to molecular biology and studies on cell-free protein and cell-wall synthesis, which led to work on the mode of action of tetracycline and several other antibiotics.

In 1969 Dr. Laskin joined Exxon Research and Engineering Company to head the laboratory program concerned with single-cell protein. In 1971 he moved to his present position, heading the research on petroleum microbiology and enzymology.

Dr. Laskin is past president of the Society of Industrial Microbiology and the Theobald Smith Society (New Jersey Branch, American Society for Microbiology) and was National Councilor for many years. He was Vice-Chairman of the local committee for the 1965 ASM National Meeting in Atlantic City and served as Chairman for the 1976 meeting. He was Chairman of the Environmental and General Applied Microbiology Division of ASM, Chairman of the Fermentation Division, and is presently a Divisinal Group Councilor, coordinating the activities of four divisions of the Society. He was also on the Membership Committee of ASM and served as Chairman of its Sustaining Membership Sub-Committee. In addition, Dr. Laskin was Chairman of the Microbiology Section of the New York Academy of Sciences. He is a member of the Panel on Microbial Degradation of Oil of the American Petroleum Institute and was Chairman of a subgroup for a National Academy of Sciences/National Research Council Panel on Underutilized Microbial Processes of Potential Value.

In 1974 Dr. Laskin was awarded the Selman A. Waksman Honorary Lectureship Award. He is a fellow of the American Academy of Microbiology and a Fellow of the New York Academy of Sciences. In 1971 to 1972 he was a Foundation for Microbiology Lecturer, and in 1977 he was the I. M. Lewis (Texas Branch, ASM) Lecturer.

Dr. Laskin is not only Co-Editor of the *CRC Handbook of Microbiology* and of *CRC Critical Reviews in Microbiology*, but also of a series entitled *Methods in Molecular Biology* as well as of the books *Extracellular Microbial Polysaccharides, The Problems of Drug-Resistant Bacteria,* and *The Genetics of Industrial Microorganisms*. In addition, he serves as Editor for a series of books on microbiology. Dr. Laskin has also authored and co-authored reviews on the mode of action of tetracycline and on single-cell protein, and has organized and chaired numerous symposia, seminars, and conferences.

THE EDITORS

Hubert A. Lechevalier, Professor of Microbiology and Associate Director at the Waksman Institute of Microbiology of Rutgers University, New Brunswick, N.J., received a Licence ès Sciences Naturelles (*summa cum laude*) in 1947 and his M.S. degree (*cum laude*) in 1948 from Laval University, Quebec City, Canada. He obtained his Ph.D. from Rutgers University in 1951.

Dr. Lechevalier remained at Rutgers University as Assistant Professor of Microbiology from 1951 to 1956, and subsequently as Associate Professor, before advancing to Professor in 1966. Within this period he also was an exchange scientist at the Academy of Sciences of the U.S.S.R. in Moscow, Visiting Investigator at the Czechoslowak Academy of Sciences in Prague, and Visiting Investigator at the Pasteur Institute, Section of Mycology, in Paris. His research, dealing with actinomycetes and their products, has led to U.S. patents for neomycin and candicidin as well as to 16 foreign patents.

A recipient of Fellowships from the National Research Council of Canada, from Rutgers University, and from the U.S. Public Health Service, Dr. Lechevalier was also awarded membership in Sigma Xi and is an Associate Member of the Société Francaise de Microbiologie. In 1976 he received the Lindbach Award for Distinguished Research and in 1982, jointly with his wife Mary, the Charles Thom Award of the Society for Industrial Microbiology for outstanding contributions in the field of industrial microbiology.

In addition to his membership in the American Society for Microbiology (ASM), in the Canadian Society for Microbiologists, the Society for Industrial Microbiology, and in the Mycological Society of America, Dr. Lechevalier has served as a participant on the Editorial Boards of *Applied Microbiology* and of *Annales de Microbiologie,* on the subcommittee on the Taxonomy of the Actinomycetes of the International Committee on Bacteriological Nomenclature, on the Subcommittee on Tastes and Odors of the American Water Works Association, and on the ASM Archives Committee. He also served as Chairman of the ASM Subcommittee on Actinomycetes, as a Trustee of the American Type Culture Collection, and as consultant to various industrial and legal firms.

Dr. Lechevalier is not only Co-Editor of the *CRC Handbook of Microbiology* and a former Co-Editor of *CRC Critical Reviews in Microbiology*, but has also collaborated on a number of books: *A Guide to the Actinomycetes and Their Antibiotics; Neomycin — Nature, Formation, Isolation, and Practical Application; Neomycin — Its Nature and Practical Application; Antibiotics of Actinomycetes; Three Centuries of Microbiology; The Microbes.* He has also authored or co-authored numerous papers.

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CRC HANDBOOK OF MICROBIOLOGY

EDITORS:
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H. A. Lechevalier, Ph.D.

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MICROBIAL TRANSFORMATIONS OF CYCLIC HYDROCARBONS

William E. Gledhill

Table 1
MICROBIAL PRODUCTS FROM BENZENE

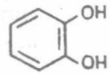
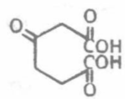
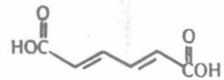
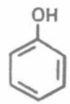
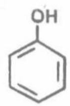
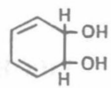
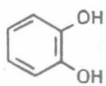
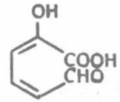
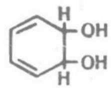
Substrate	Concentration	Organism[a]	Product[b]	Yield	Length of fermentation	Remarks	Ref.
Benzene 		*Mycobacterium rhodochrous* *Pseudomonas aeruginosa*	Catechol 	—	24—48 hr		1
			cis,cis-Muconic acid 	—			
			β-Ketoadipic acid 	—			
			Succinic acid 	—			

Table 1 (continued)
MICROBIAL PRODUCTS FROM BENZENE

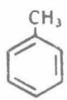
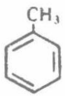
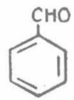
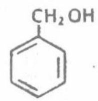
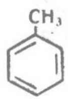
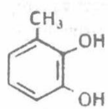
Substrate	Concentration	Organism[a]	Product[b]	Yield	Length of fermentation	Remarks	Ref.
Benzene 	—	*Micrococcus sphaeroides* *Nocardia corallina*	*trans,trans*-Muconic acid  Phenol 	—		Evidence for phenol from sequential induction experiments	2 3
Benzene 	—	*Gram-positive rod*	Phenol 	—			4
Benzene 	—	*Pseudomonas putida* B	*cis*-Benzene glycol 	—		Washed-cell suspensions and cell-free extracts employed	5
			Catechol 	—			

			2-Hydroxymuconic semialdehyde 	—			
Benzene 	3 g/ℓ	*Pseudomonas putida* 39/D	*cis*-1,2-Dihydro-1,2-dihydroxybenzene 	1.1 g/ℓ	30 hr	Glucose-grown benzene-induced resting cells used	6

[a] Organisms listed above represent genera or species that, when used as pure cultures, have been reported to form the particular product(s). Each organism utilizing a particular substrate forms all of the products listed.

[b] The listing of two or more products from a particular substrate indicates that they are found together at the end of the fermentation.

Table 2
MICROBIAL PRODUCTS FROM METHYL-SUBSTITUTED BENZENES AS THE SOLE CARBON AND ENERGY SOURCE

Substrate	Concentration	Organism[a]	Product[b]	Yield	Length of fermentation	Remarks	Ref.
Toluene 	—	*Pseudomonas aeruginosa*	Benzoic acid 	—		Cell-free extracts employed	7
Toluene 	—	*Pseudomonas aeruginosa*	Benzaldehyde 	—		Toluene-adapted acetone-dried cells	8
			Benzoyl alcohol 	—			
Toluene 	—	*Achromobacter* *Pseudomonas* sp.	3-Methylcatechol 	3.9 mg/ℓ		Washed-cell suspensions of toluene-grown cells	5[c] 9 10

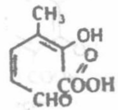
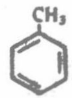
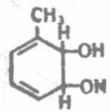
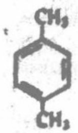
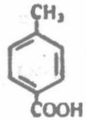
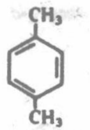
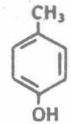
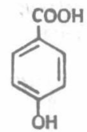
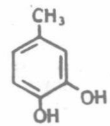
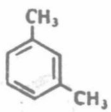
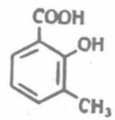
Toluene 	—	*Pseudomonas putida*	Methyl-α-hydroxy-muconic semialdehyde 	—			11
Toluene 	**0.46 g/ℓ**	*Achromobacter Pseudomonas* sp. *mildenbergii*	Pyruvic acid $CH_3\overset{\overset{O}{\|}}{C}\overset{\overset{O}{\|}}{C}OH$	0.27 g/ℓ			9[c] 12
			Acetic acid $CH_3\overset{\overset{O}{\|}}{C}OH$	0.26 g/ℓ			
Toluene 	—	*Pseudomonas putida* 39/D	(+)-*cis*-2,3-Dihydro-2,3-dihydroxytoluene 	1.5 g/ℓ	60 hr	Parent organism grows readily on toluene, but the 39/D mutant requires glucose or yeast extract for growth	14
***p*-Xylene** 	**17.2 g/ℓ**	***Pseudomonas* S668B2 sp. *Achromobacter***	*p*-Toluic acid 	3.4 g/ℓ		Product formation during log phase (before 20 hr)	7 13 15[c]

Table 2 (continued)
MICROBIAL PRODUCTS FROM METHYL-SUBSTITUTED BENZENES AS THE SOLE CARBON AND ENERGY SOURCE

Substrate	Concentration	Organism[a]	Product[b]	Yield	Length of fermentation	Remarks	Ref.
p-Xylene 	17.2 g/ℓ	*Pseudomonas aeruginosa* S668B2	*p*-Cresol 	—		Products accumulate in low quantities	16
			p-Hydroxybenzoic acid 	—			
			4-Methylcatechol 	—			
m-Xylene 	17.2 g/ℓ	*Pseudomonas aeruginosa S668B2*	3-Methylsalicylic acid 	120 mg/ℓ			17