

CRC

HANDBOOK  
*of*  
MICROBIOLOGY  
2nd Edition

Volume III  
Microbial Composition: Amino Acids,  
Proteins, and Nucleic Acids  
A. I. Laskin  
H. A. Lechevalier

CRC

PRESS

# CRC Handbook of Microbiology

2nd Edition

## Volume III Microbial Composition: Amino Acids, Proteins, and Nucleic Acids

Editors

**Allen I. Laskin, Ph.D.**  
Exxon Research and Engineering Company

**Hubert A. Lechevalier, Ph.D.**  
Waksman Institute of Microbiology  
Rutgers University

**Library of Congress Cataloging in Publication Data (Revised)**

Main entry under title:

CRC handbook of microbiology.

Includes bibliographical references and indexes.

CONTENTS: v. 1. Bacteria.--v. 2. Fungi, algae, protozoa, and viruses.--v. 3. Microbial composition: amino acids, proteins, and nucleic acids.

I. Microbiology--Collected works. I. Laskin, Allen I., 1928- II. Lechevalier, Hubert A. III. Chemical Rubber Company, Cleveland. IV. Title: Handbook of microbiology. [DNLM: 1. Microbiology. QW4 H234 1977]

QR6.C2 1977      576      77-12460

ISBN 0-8493-7200-3

This book represents information obtained from authentic and highly regarded sources. Reprinted material is quoted with permission, and sources are indicated. A wide variety of references are listed. Every reasonable effort has been made to give reliable data and information, but the author and the publisher cannot assume responsibility for the validity of all materials or for the consequences of their use.

All rights reserved. This book, or any parts thereof, may not be reproduced in any form without written consent from the publisher.

Direct all inquiries to CRC Press, Inc., 2000 N.W. 24th Street, Boca Raton, Florida 33431.

© 1981 by CRC Press, Inc.

International Standard Book Number 0-8493-7203-8

Library of Congress Card Number 77-12460  
Printed in the United States

## PREFACE

The 1st Edition of the *CRC HANDBOOK OF MICROBIOLOGY* consisted of four volumes; Volume II was entitled *Microbial Composition*. For this 2nd Edition of the *Handbook*, the revised enlarged material could not be conveniently bound within a single cover. Thus, we decided to divide the material into two separate volumes. This, Volume III of the 2nd Edition includes information on proteins and nucleic acids, and takes its place behind the first two volumes, which deal with the microorganisms themselves: the *Bacteria* (Volume I) and the *Fungi, Algae, Protozoa, and Viruses* (Volume II). Volume IV includes information on carbohydrates, lipids, and minerals.

We have added, to material found in the 1st Edition, several sections from the 3rd Edition of the *CRC HANDBOOK OF BIOCHEMISTRY*. This was done in the hope that the needs of many microbiologists will be satisfied without having to purchase two different sets of handbooks.

We join the staff of CRC Press in extending our thanks to members of the Advisory Board and especially to all the authors who have worked unselfishly to make the 2nd Edition of the *Handbook* possible.

We also wish to thank Mrs. Verna Lepping for her excellent editorial work.

A. I. Laskin  
H. A. Lechevalier  
New Jersey, 1980

## THE EDITORS

**Allen I. Laskin**, Head of Biosciences Research at Exxon Research and Engineering Company, Linden, 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 twenty 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 Divisional 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—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 at Rutgers University, New Brunswick, N. J., received a Licence es 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 his present position 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 Czechoslovak Academy of Sciences in Prague, and Visiting Investigator at the Pasteur Institute, Section of Mycology, in Paris. His research during those years led to U.S. patents for neomycin and candicidin as well as to sixteen 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 Societe Francaise de Microbiologie. In 1976 he received the Lindbach Award for Distinguished Research.

In addition to his membership in the American Society for Microbiology, 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 AMS 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.

## ADVISORY BOARD

### CHAIRMAN

**Hans-Wolfgang Ackermann, M.D.**

Department of Microbiology  
Faculty of Medicine  
Laval University  
Quebec, P. Q., Canada

### Members

**Carl F. Clancy, Ph.D.**

Department of Microbiology  
Jefferson Medical College  
Thomas Jefferson University  
Philadelphia, Pennsylvania

**Cecil S. Cummins, Sc.D.**

Anaerobe Laboratory  
Virginia Polytechnic Institute and State  
University  
Blacksburg, Virginia

**Martin Dworkin, Ph.D.**

Department of Microbiology  
University of Minnesota  
Minneapolis, Minnesota

**Eugene R. L. Gaughran, Ph.D.**

Research Center  
Johnson & Johnson  
North Brunswick, New Jersey

**Nancy N. Gerber, Ph.D.**

Waksman Institute of Microbiology  
Rutgers University  
New Brunswick, New Jersey

**S. H. Hutner, Ph.D.**

Haskins Laboratories and Department  
of Biology  
Pace University  
New York, New York

**Karl Maramorosch, Ph.D.**

Waksman Institute of Microbiology  
Rutgers University  
New Brunswick, New Jersey

**Yoshiro Okami, Ph.D.**

Institute of Microbial Chemistry  
Microbial Chemistry Research  
Foundation  
Shinagawa-Ku, Tokyo, Japan

**William M. O'Leary, Ph.D.**

Department of Microbiology  
Cornell University Medical College  
New York, New York

**David Perlman, Ph.D.**

School of Pharmacy  
University of Wisconsin  
Madison, Wisconsin

**Frank Persico, Ph.D.**

Biochemical Research  
Ortho Pharmaceutical Corporation  
Raritan, New Jersey

**Herman J. Phaff, Ph.D.**

Department of Food Science and  
Technology  
College of Agricultural and  
Environmental Sciences  
University of California  
Davis, California

**Thomas B. Platt, Ph.D.**

Bioanalytical Section  
The Squibb Institute of Medical  
Research  
New Brunswick, New Jersey

**Otto J. Plescia, Ph.D.**

Waksman Institute of Microbiology  
Rutgers University  
New Brunswick, New Jersey

**Chase Van Baalen, Ph.D.**  
Marine Science Institute  
University of Texas  
Port Aransas, Texas

**Claude Vezina, Ph.D.**  
Department of Microbiology  
Ayerst Research Laboratories  
St. Laurent, P. Q., Canada

**L. C. Vining, Ph.D.**  
Department of Biology  
Dalhousie University  
Halifax, N. S., Canada

**E. D. Weinberg, Ph.D.**  
Department of Biology  
Program in Medical Sciences  
Indiana University  
Bloomington, Indiana

## CONTRIBUTORS

**H. W. Ackerman, Ph.D.**

Department of Microbiology  
Faculty of Medicine  
Laval University  
Quebec, Canada

**Harold Drabkin, Ph.D.**

Biology Department  
Massachusetts Institute of Technology  
Cambridge, Massachusetts

**T. O. Diener, Ph.D.**

Agricultural Research Service  
Plant Virology Laboratory  
Beltsville, Maryland

**William Firshein, Ph.D.**

Wesleyan University  
Middletown, Connecticut

**Jeanne-Pierre Garel**

Universite Claude Bernard Lyon-I  
Departement de Biologie et Applique  
FRANCE

**David H. Gillespie, Ph.D.**

Public Health Service  
National Cancer Institute  
Bethesda, Maryland

**Albert Goze, Ph.D.**

Centre National de la Recherche  
Scientifique  
FRANCE

**Roger Guay, Ph.D.**

Department of Microbiology  
Faculty of Medicine  
Laval University  
Quebec, Canada

**J. C. MacDonald, Ph.D.**

National Research Council of Canada  
Saskatoon, Saskatchewan, Canada

**John A. Moore, Jr., Ph.D.**

Microbiology Laboratory  
Pittston Hospital  
Pittston, Pennsylvania

**M. R. V. Murthy, Ph.D.**

Department of Microbiology  
Laval University  
Quebec, Canada

**James Ofengand, Ph.D.**

Biochemistry Department  
Roche Institute of Molecular Biology  
Nutley, New Jersey

**M. A. Q. Siddiqui, Ph.D.**

Roche Institute of Molecular Biology  
Nutley, New Jersey

**M. R. Guy Smith**

Public Health Service  
National Cancer Institute  
Bethesda, Maryland

**David H. Strumeyer, Ph.D.**

Department of Biochemistry and  
Microbiology  
Rutgers University  
New Brunswick, New Jersey

**Jan S. Tkacz, Ph.D.**

Rutgers University  
Waksman Institute of Microbiology  
Piscataway, New Jersey

## TABLE OF CONTENTS

<b>Amino Acids and Proteins</b> .....	1
Structures of Amino Acids Occurring in Proteins .....	3
Data on the Naturally Occurring Amino Acids .....	11
Optical Isomers and Ionization Constants of Amino Acids .....	77
Ionization Constants .....	80
$\alpha$ , $\beta$ -Unsaturated Amino Acids .....	83
Solubilities of the Amino Acids in Water at Various Temperatures .....	85
Properties of the $\alpha$ -Keto Acid Analogs of Amino Acids .....	89
Far-Ultraviolet Absorption Spectra of Amino Acids .....	91
Ultraviolet Absorption Characteristics of N-Acetyl Methyl Esters of the Aromatic Amino Acids, Cystine, and N-Acetylcysteine .....	93
Absorption Spectra of the Aromatic Amino Acids at pH6 .....	95
Absorbance Values of the Aromatic Amino Acids in Neutral, Alkaline, and Acid Solutions .....	97
Specific Rotations of Amino Acids .....	101
Amino Acid Antagonists .....	109
 <b>Amino Acid Sequence of Proteins</b> .....	117
Amino Acid Sequences of Some Coat Proteins .....	119
Amino Acid Sequences of Virus Coat Proteins .....	121
Amino Acid Sequences of Virus Coat Proteins .....	123
Location of Some Amino Acid Replacements in Naturally Occurring (NM) and Chemically Induced (CM) Mutants of TMV .....	125
Amino Acid Sequences of Miscellaneous Proteins .....	127
Amino Acid Sequences of Enzymes .....	129
Amino Acid Sequences of Prokaryotic Cytochromes c .....	135
Amino Acid Sequence of Ferredoxins and Relatives .....	153
Amino Acid Sequence of <i>Streptomyces albogriseolus</i> Alkaline Proteinase Inhibitor .....	161
Amino Acid Composition of Tailed Bacteriophages .....	163
Components of the Ribosome .....	173
Numbering and Classification of Enzymes .....	191
 <b>Nucleic Acids</b> .....	199
Purines, Pyrimidines, Nucleosides, and Nucleotides: Physical Constants and Spectral Properties .....	201
Natural Occurrence of the Modified Nucleosides .....	351
Metabolism of Nucleosides .....	387
Metabolism of Ribonucleosides .....	393
Isolation and Enzymatic Synthesis of Sugar Nucleotides .....	399
Nucleoside Antibiotics: Physicochemical Constants; Spectral, Chemotherapeutic, and Biological Properties .....	413
Distribution of Purines and Pyrimidines in Deoxyribonucleic Acids .....	535
Guanine-Plus-Cytosine (GC) Composition of the DNA of Bacteria, Fungi, Algae, and Protozoa .....	559
Base Composition of Bacteriophage Nucleic Acids .....	731
DNA Base Compositions of Eukaryotic Protists .....	751
Determination of the Molar Percentage of Guanine + Cytosine in Deoxyribonucleic Acid .....	757

<b>Appendix A: Operation of the Gilford 2000 Recording Spectrophotometer for a Thermal Melting Profile of DNA</b> .....	763
<b>Melting Temperatures (<math>T_m</math>) of Synthetic Polynucleotides</b> .....	765
<b>Buoyant Densities of Nucleic Acids and Polynucleotides</b> .....	773
<b>Spectrophotometric Constants of Ribonucleotides</b> .....	783
<b>Optical Properties of Nucleic Acids, Absorption, and Circular Dichroism</b>	
Spectra .....	787
Molecular Hybridization .....	789
Nucleic Acid Sequences .....	807
Buoyant Densities, Melting Temperatures and GC Content .....	839
Viral DNA Molecules .....	845
Deoxyribonucleic Acid Content per Cell of Various Organisms .....	855
Properties of Kinetoplast DNAs .....	863
Nearest Neighbor Frequencies in Deoxyribonucleic Acids .....	867
Content of 6-Methylaminopurine and 5-Methylcytosine in DNA .....	873
Controlled Partial Hydrolysis of RNA .....	875
General Features of tRNA Structure .....	879
Viroids .....	917
<b>Indexes</b> .....	923
Taxonomic Index .....	925
Topical Index .....	969

## ***Amino Acids and Proteins***



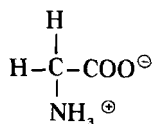
# STRUCTURES OF AMINO ACIDS

D. Strumeyer

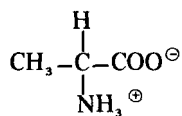
## I. Amino Acids Occurring in Proteins

### A. NEUTRAL AMINO ACIDS

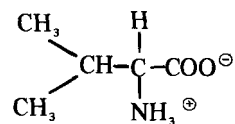
#### 1. Aliphatic



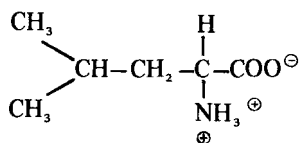
Glycine



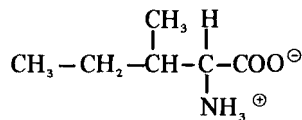
L-Alanine



L-Valine

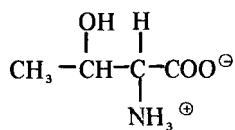


L-Leucine

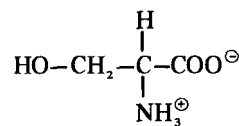


L-Isoleucine

#### 2. Hydroxyl-Containing

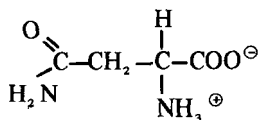


L-Threonine

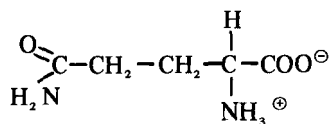


L-Serine

#### 3. Amide-Containing

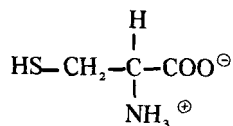


L-Asparagine

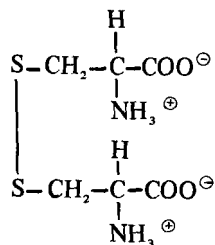


L-Glutamine

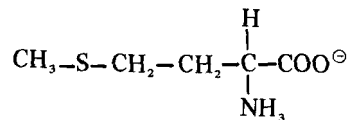
## 4. Sulfur-Containing



L-Cysteine

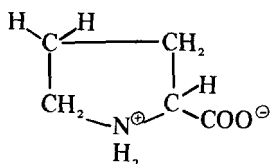


L-Cystine

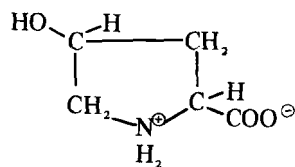


L-Methionine

## 5. Imino Amino Acids

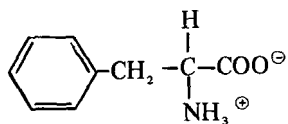


L-Proline

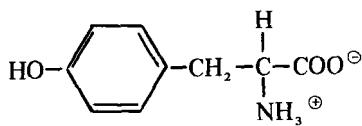


L-Hydroxyproline

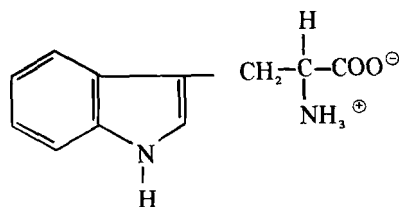
## 6. Aromatic



L-Phenylalanine

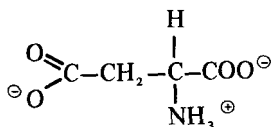


L-Tyrosine

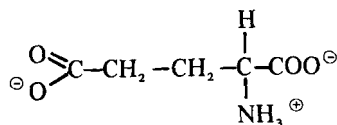


L-Tryptophan

## B. ACIDIC AMINO ACIDS

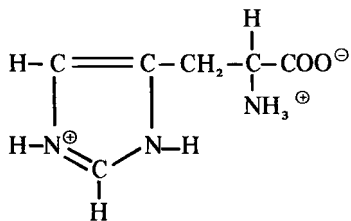


L-Aspartic acid

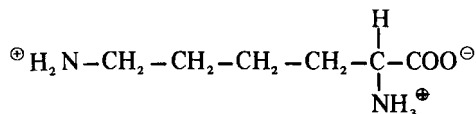


L-Glutamic acid

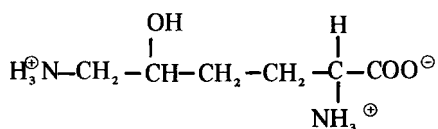
## C. BASIC AMINO ACIDS



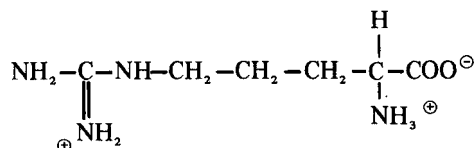
L-Histidine



L-Lysine

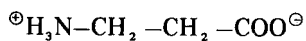
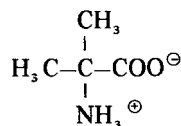
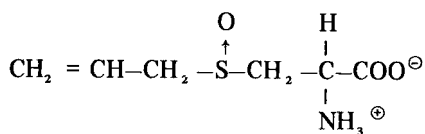


L-Hydroxylysine

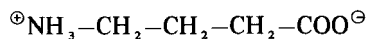
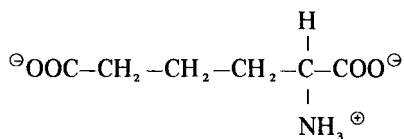
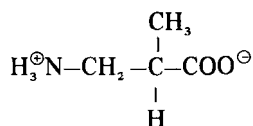
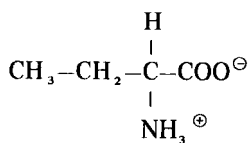
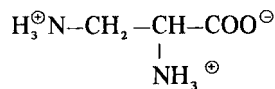


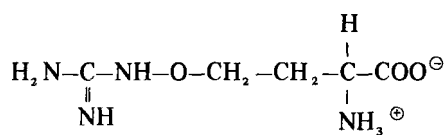
L-Arginine

## D. OTHER AMINO ACIDS AND DERIVATIVES

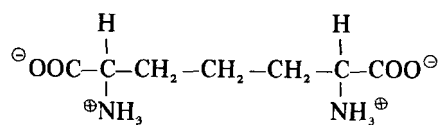
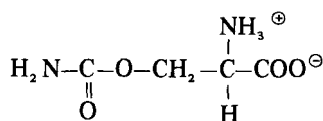
 $\beta$ -Alanine $\alpha$ -Aminoisobutyric acid

S-Allyl-L-cysteine sulfoxide

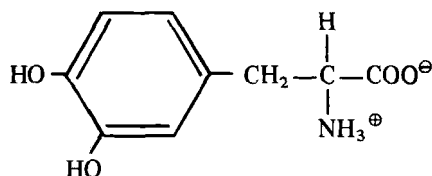
 $\gamma$ -Aminobutyric acidL- $\alpha$ -Aminoadipic acid $\beta$ -Aminoisobutyric acid $\alpha$ -Aminobutyric acid $\beta$ -Aminopropionic acid



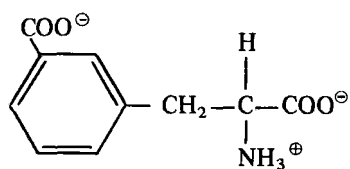
L-Canavanine

 $\alpha,\epsilon$ -Diaminopimelic acid

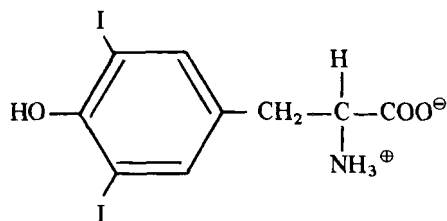
O-Carbamyl-D-serine



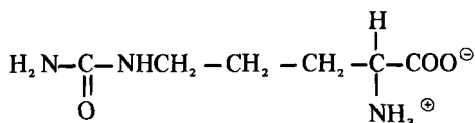
L-Dihydroxyphenylalanine



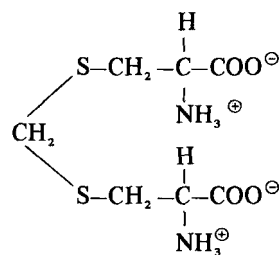
m-Carboxyphenyl-L-alanine



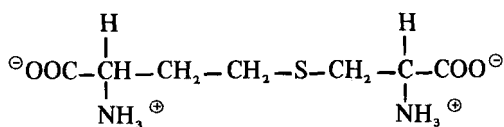
L-Diiodotyrosine



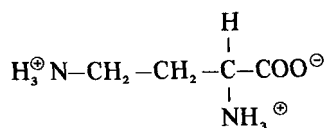
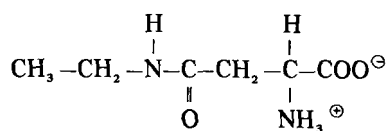
Citrulline



L-Djenkolic acid, [3,3'-(methylenedithio) dialanine]



Cystathionine

L- $\alpha,\gamma$ -diaminobutyric acidN<sup>4</sup>-Ethyl-L-asparagine