Handbook of Olfaction and Gustation

edited by
Richard L. Doty

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Handbook of Olfaction and Gustation

NEUROLOGICAL DISEASE AND THERAPY

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Series Introduction

The *Handbook of Olfaction and Gustation*, edited by Dr. Richard L. Doty, is the 32nd book in the Neurological Disease and Therapy series. This series has covered many neurological topics, including Parkinson's disease, stroke, Alzheimer's disease, sleep disorders, many aspects of epilepsy, multiple sclerosis, tics and Tourette's syndrome, cerebellar diseases, trauma of the head and spine, brain tumors, and myasthenia gravis. The series has also addressed many therapeutic issues, including the use of monoamine oxidase inhibitors and the use of botulinum toxin, and has concentrated on general disease topics, such as neurotoxicology, neurovirology, neuroepidemiology, neurorehabilitation, and tremor disorders. The goal of the series is to provide comprehensive books on topics that are important to the clinical neurologist, providing both the basic neurological aspects as well as practical clinical information for everyday management of patients. The series covers a broad spectrum of our knowledge on neurological disorders. It is hoped that these books represent important reference texts in which the clinician can quickly find pertinent information for use in managing patients. Future books in the series will concentrate on the emerging knowledge in neurology and how it is being translated into the care of patients in the clinic.

The *Handbook of Olfaction and Gustation* discusses in great detail the many aspects pertinent to olfaction. We take our ability to smell for granted; however, many conditions and diseases may disturb this important special sensory function. The first section details anatomy, biochemistry, and physiology of olfaction. Next, human psychophysics and measurement of odor-induced responses are discussed. The third section consists of eight chapters of clinical applications and perspectives. The topic of gustation, which is covered under three section headings similar to the part on olfaction, is articulated in great detail. The final three chapters discuss other chemosensory systems. This handbook is in keeping with other books in the series and succeeds in providing state-of-the-art knowledge on the basic and clinical aspects of olfaction and gustation.

William C. Koller

Preface

Until recently, the senses of taste and smell have been an enigma to scientists and lay persons, largely because of inherent difficulties in exploring their biologic bases and the widely propagated myth that they are of little importance to humans. Fortunately, remarkable progress has been made in the last few decades in understanding the function of these senses and in dispelling this myth.

The increase of interest in the chemical senses by scientists and physicians reflects, in part, general public awareness of their importance in everyday life and the debilitation that follows their damage or dysfunction. These senses are of particular interest to the biomedical community, given (1) their involvement in a variety of behavioral and endocrine responses, (2) the ability of the olfactory neurons to regenerate (the understanding of which may be of value in promoting regeneration in other neural tissue), (3) epidemiological evidence that occupational exposure to some chemicals compromises chemosensation, and (4) the discovery that olfactory dysfunction can arise from many sources, including systemic diseases, head trauma, nasal and paranasal sinus disease, exposure to toxic chemicals, brain tumors, schizophrenia, and a number of neurodegenerative disorders. Of specific relevance to the neurologist is the observation that decreased olfactory function may be the first clinical manifestation of Alzheimer's disease and idiopathic Parkinson's disease. This observation, along with neuropathological and histochemical studies of affected neural tissue, has led to the intriguing hypothesis that environmental agents associated with the etiology or catalysis of these disorders may enter the brain via the olfactory fila.

The *Handbook of Olfaction and Gustation* represents a synthesis of a large body of basic and clinical knowledge on the senses of taste and smell, providing an up-to-date, comprehensive treatise related to the fundamentals of chemosensory science. Clinical relevance is emphasized, as is historical perspective, and a considerable amount of material has been compiled that is unavailable elsewhere. Importantly, contributions that incorporate recent developments in molecular biology are provided.

While the *Handbook* is one volume in a successful series designed primarily for the neurologist, it provides information useful to a wide range of medical practitioners and basic scientists, as well as to medical students and graduate students from a number of disciplines. Indeed, this book can easily serve as a textbook on chemoreception science, as well as a basic reference

book. Among the unique chapters of this volume are those on (1) the biochemistry of saliva, (2) the neurochemistry of the olfactory bulb, including its centrifugal inputs, (3) current trends in the psychophysical and electrophysiological measurement of taste and smell function, (4) the genetics of chemosensation, (5) the movement of viruses and other agents from the nasal cavity into the brain via the olfactory nerves, (6) the influences of sensory deprivation on the olfactory system, (7) the complex interplay between airway dynamics and the ability to smell, (8) perception of tastant and odorant mixtures, (9) adaptation of the olfactory and gustatory systems, (10) conditioned taste and flavor aversions, (11) iatrogenic causes of taste disturbances, and (12) the anatomy and function of vomeronasal and nervus terminalis systems.

Sixty leading authorities from a wide variety of basic science and clinical disciplines contributed to the *Handbook*. Such disciplines include the fields of anatomy, biochemistry, developmental and molecular neurobiology, genetics, immunohistochemistry, neurology, nutrition, otorhinolaryngology, pharmacology, physiology, radiology, sensory psychology, toxicology, and virology. Considerable effort was made to include outstanding scientists whose viewpoints are not widely known and who provide fresh insight on a number of issues. Nearly a quarter of the authors are practicing medical specialists who address chemosensory problems on a regular basis and thus bring to their chapters practical information derived from clinical practice.

A goal of the *Handbook* is to present the information in as straightforward manner as possible. Therefore, the chapters are conveniently arranged into three major parts corresponding to olfaction, gustation, and other chemosensory systems and, with the exception of the last section, are subdivided into three divisions: (1) anatomy, biochemistry, and physiology, (2) psychophysics and measurement of stimulus-induced responses, and (3) clinical applications and perspectives.

I am grateful to Dr. William C. Koller, who invited me to prepare this volume for his series, the contributors to the volume, the members of the Smell and Taste Center, and the staff of Marcel Dekker, Inc., for their help and consideration in the preparation of this work. I am also indebted to the National Institute on Deafness and Other Communication Disorders, without whose support (PO1DC 00161) this endeavor would not have been possible.

Richard L. Doty

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Introduction and Historical Perspective

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I. INTRODUCTION

All environmental nutrients and airborne chemicals required for life enter our bodies by the nose and mouth. The senses of taste and smell monitor the intake of such materials, not only warning us of environmental hazards, but determining, in large part, the flavor of our foods and beverages. These senses are very acute; for example, the human olfactory system can distinguish among thousands of airborne chemicals, often at concentrations below the detection limits of the most sophisticated analytical instruments (Takagi, 1989). Furthermore, these senses are the most ubiquitous in the animal kingdom, being present in one form or another in nearly all air-, water-, and land-dwelling creatures. Even bacteria and protozoa have specialized mechanisms for detecting environmental chemicals–mechanisms whose understanding may be of considerable value in explaining their modes of infection and reproduction (Jennings, 1906; Russo and Koshland, 1983).

While the scientific study of the chemical senses is of relatively recent vintage, the role of these senses in the everyday life of humans undoubtedly extends far into prehistoric times. For example, some spices and condiments, including salt and pepper, likely date back to the beginnings of rudimentary cooking, and a number of their benefits presumably were noted soon after the discovery of fire. The release of odors from plant products by combustion was undoubtedly an early observation, the memory of which is preserved in the modern word *perfume*, which is derived from the Latin *per* meaning "through" and *fumus* meaning "smoke." Fire, with its dangerous and magical connotations, must have become associated early on with religious activities, and pleasant-smelling smoke was likely sent into the heavens in rituals designed to please or appease the gods. Importantly, food and drink became linked to numerous social and religious events, including those that celebrated birth, the attainment of adulthood, graduation to the status of hunter or warrior, and the passing of a soul to a better life.

The goal of this introduction is to provide a brief historical overview of (1) the important role that tastes and odors have played in the lives of human beings throughout millennia and (2) key observations from the last four centuries that have helped to form the context of modern chemosensory research. Recent developments, a number of which are described in more detail in other contributions to the *Handbook*, are briefly mentioned to whet the reader's appetite for