TASTES & AROMAS

THE CHEMICAL SENSES IN SCIENCE AND INDUSTRY

EDITED BY
GRAHAM A. BELL
ANNESLEY J. WATSON

UNSW PRESS

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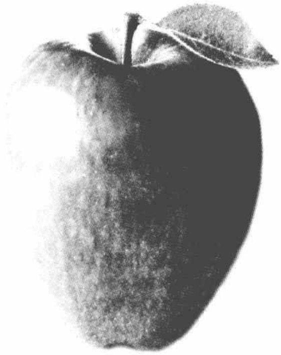


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Blackwell Science

UNSW PRESS

This volume was published with support from

The Centre for ChemoSensory Research, the University of New South Wales, Sydney, Australia

and

The Cooperative Research Centre for International Food Manufacture and Packaging Science, Australia

A UNSW Press book

Published by
University of New South Wales Press Ltd
University of New South Wales
Sydney 2052 Australia
http://www.unswpress.com.au

First published 1999

National Library of Australia
Cataloguing-in-Publication entry:

Tastes and aromas: the chemical senses in science and industry.

Includes index.
ISBN 0 86840 769 0.

1. Research, Industrial. 2. Science and industry. 3.Taste. 4. Smell. I. Bell, Graham A. II. Watson, Annesley J.

573.877

Printer Everbest Printing, Hong Kong

TASTES & AROMAS

Graham Bell, Director of the Centre for ChemoSensory Research at the University of New South Wales and Adjunct Associate Professor in the School of Physiology and Pharmacology, has been a practising professional scientist in the chemical senses for two decades. He is well known internationally for his research on the fundamentals of smell and taste, the development of novel sensors and the psychology of food.

Annesley Watson is the sensory analyst for Arnott's Biscuits and is the current Chair of the New South Wales division of Australian Institute of Food Science and Technology (AIFST). She has pioneered the application of chemosensory research in the food industry.

PREFACE

Interest in the chemical senses, in particular smell, taste and pungency, is growing in scientific and industrial circles.

This book offers new information to readers with training and industrial needs. Reviewing the progress being made in chemosensory science and technology shows that this research field does and will provide solutions to industrial problems now and in the future.

Practitioners of sensory research in industry should, by reading this book, be provided with new facts and ideas to contemplate, in the context of their specific needs.

The field of chemical senses covers a wide area of science and technology. We cannot attempt to cover all the known and visible territory, which would take many volumes. Instead we must act as your guide and take you into the minds of prominent individuals in this field and let them describe their small part of it, so that in the end you will know some of the most salient features of the chemosensory landscape and how you might derive benefit from it.

The first four chapters provide introductions to the chemical senses and the important questions currently being studied. We begin with people's earliest thoughts about smell and taste, in the first chapter by Michael Stoddart, a renowned biologist who has made a comprehensive study of chemical communication in humans and other animals. We are reminded of mankind's culturally longstanding fascination with scents, and of their origins in evolution.

Yale University's Linda Bartoshuk and her co-workers then introduce the taste senses, with a perspective on variations that exist in the human population and their implications for food choice, diet and health.

Steven Youngentob gives a clear introduction to the sense of smell, which has for so long been regarded as largely mysterious, but which is now becoming understood at cellular and molecular levels and is generating new technologies, some of which are introduced in this volume.

John Prescott introduces the topic of pungency (the trigeminal sense). Long regarded as too difficult to measure systematically in human beings, the burn of chilli is now a 'hot topic' in food and flavour, with valuable spin-off to the food, confectionery and beverage product developer.

The next five chapters look at value-adding applications of smell and taste research around the world: in Europe (David Lyon), Australia (Jennifer Weller), Asia (Graham Bell and Hae-Jin Song), Japan (Sachiko Saito, *et al.*) and Indonesia (Kerry Easton and Graham Bell).

We then look at two major industrial applications for chemosensory research: the fragrance and wine industries, with chapters by Dragoco Australia's John Lambeth and Ann Noble of the University of California (Davis). These chapters show the central role for human sensory research in developing successful products in billion-dollar global markets.

As human sensory research draws on statistical analysis for sound interpretation of results, we include two chapters illustrating new statistical and design tools for the sensory practitioner by John Best and colleagues and by James Walker and Martin Kendal-Reed.

The following three chapters, by Peter Barry, Susan Sullivan and Brian Key, tell of important fundamental progress in smell and taste research. Anatomical and physiological methods are slowly but surely cracking the process by which chemical compounds are recognised by the mouth and nose and how sensation is transformed into thoughts and feelings. Graham Bell shows in the next chapter that progress on three basic molecular mechanisms of olfaction offers exciting prospects for a range of technologies.

The book concludes with five chapters on artificial chemical sensing. These chapters focus on devices that are now being made to mimic the nose and brain. Alan Mackay-Sim tells of sensor research that will allow miniature robots to follow scent trails and Jelle Atema shows how the crayfish nose can be copied in an underwater 'robo-lobster'. While these may evoke images of demonic toys, they have serious applications in environmental and security industries. Brynn Hibbert reveals how sensors can be used to monitor air and motor vehicle pollution, and Don Barnett describes what is needed for a sensor system to perform a range of valuable tasks in a food factory. David Levy concludes with a clear explanation of artificial neural networks, by which complex information of the kind produced by the senses of smell and taste can be processed and categorised. The brain and the artificial neural net both learn that four hundred volatiles are actually one thing: the smell of chocolate.

Whether you are approaching the science of smell, taste and pungency for the first time or are already involved in teaching, in research or professional practice, we hope all readers will find this book rewarding and will gain useful new perspectives and enhanced appreciation of chemosensory science.

ACKNOWLEDGMENTS

Our sincere thanks go to Roger Edwards and the CRC for International Food Manufacture and Packaging Science for their support of the seminar called 'Sensory Science: Meeting Industry Needs' held in Sydney in November 1996, from which this volume originated; Marilyn Styles of the UNSW Centre for ChemoSensory Research for communicating with authors; John Prescott of the University of Otago, New Zealand, for his insights and assistance in the formulation of the original meeting; and John Elliot of UNSW Press for his valuable commitment to the project. Our thanks also go to Jane Paton and Richard Bell for reading and proofing the final drafts.

One special mention is well deserved: Karyn Weitzner tirelessly desk-edited this volume. We appreciate her skills and her patience.

Naturally, this collection of chapters is nothing without its individual authors. Thanks go to each and every one for giving their time to come to Australia and Sydney and later for their responses when required, particularly as each has updated the original papers for maximum contemporary value to the reader.

CONTRIBUTORS

Editors
Graham Bell and Annesley Watson

CHAPTER 1

D.M. Stoddart
Contact
D. Michael Stoddart
ANARE Chief Scientist
Australian Antarctic Division
Channel Highway
Kingston, TAS 7050, Australia

CHAPTER 2

L.M. Bartoshuk (Yale University School of Medicine), K.E. Cunningham (Yale University School of Medicine), G.M. Dabrila (Yale University School of Medicine), V.B. Duffy (University of Conneticut), L. Etter (Yale University School of Medicine), K.R. Fast (Yale University School of Medicine, University of Conneticut), L.A. Lucchina (Yale University School of Medicine), J.M. Prutkin (Yale University School of Medicine), D.J. Snyder (Florida State University)
Contact
Professor L.M. Bartoshuk
Department of Surgery
Yale University School of Medicine
333 Cedar St.
New Haven, CT 06520-8041, USA

CHAPTER 3

S.L. Youngentob
Contact
Dr S.L. Youngentob
Dept. of Neuroscience and Physiology and The SUNY Clinical Olfactory Research Center
SUNY Health Science Center
Syracuse, NY 13210, USA

CHAPTER 4

J. Prescott
Contact
Dr J. Prescott
Sensory Science Research Centre
University of Otago
PO Box 56
Dunedin, New Zealand

CHAPTER 5

D.H. Lyon
Contact
D.H. Lyon
Head of Department of Sensory Quality and Food Acceptability
Campden and Chorleywood Food Research Association, UK
Gloucestershire, GL556LD, UK

CHAPTER 6

J. Weller
Contact
J. Weller
Sensory Research Manager
Uncle Tobys
Murray Valley Highway
Rutherglen VIC 3685, Australia

CHAPTER 7

G.A. Bell and Hae-Jin Song
Centre for ChemoSensory Research, University of New South Wales
Contact
Associate Professor G.A. Bell,
Centre for ChemoSensory Research
University of New South Wales
Australian Technology Park,
Sydney, NSW 1430, Australia

CHAPTER 8

S. Saito (National Institute of Bioscience and Human Technology (NIBH), Agency of Industrial Science and Technology (AIST), Ministry of International Trade and Industry (MITI), Japan), S. Ayabe-Kanamura (NIBH, AIST, MITI, Japan; Institute of Psychology, University of Tsukuba, Japan); T. Kobayakawa (NIBH, AIST, MITI), Japan); Y. Kuchinomachi (NIBH, AIST, MITI), Japan); and Y. Takashima (Takasago Int. Corp., Japan)
Contact
Sachiko Saito
NIBH, AIST, MITI
Higashi 1-1, Tsukuba,
Ibaraki 305-0046, Japan

CHAPTER 9

K. Easton (Food Science Australia) and G.A. Bell (Centre for ChemoSensory Research, University of New South Wales)
Contact
Kerry Easton
Food Science Australia
P.O. Box 52
Sydney NSW 1670, Australia

CHAPTER 10

J. Lambeth
Contact
J. Lambeth
Fragrance Designer
Dragoco Australia Pty Ltd
PO Box 643
Dee Why, NSW 2099, Australia

CHAPTER 11

A.C. Noble
Contact
Professor A.C. Noble
Department of Viticulture and Enology
University of California
One Shields Ave
Davis, CA 95616, USA

CHAPTER 12

J.C. Walker (FSU Sensory Research Institute, NHMFL), M. Kendal-Reed (Cranio-Facial Centre, School of Dentistry, University of North Carolina) and W.T. Morgan (Research and Development, Bowman Gray Technical Centre, R.J. Reynolds Tobacco Co).
Contact
J. Walker
FSU Sensory Research Institute
NHMFL
Tallahassee, FL 32306, USA

CHAPTER 13

D.J. Best (CSIRO Mathematical and Information Sciences), J.C.W. Rayner (School of Mathematics and Applied Statistics, University of Wollongong) and M. O'Sullivan (CSIRO Mathematical and Information Sciences)
Contact
D.J. Best
CSIRO Mathematical and Information Sciences
PO Box 52
Sydney, NSW 2113, Australia

CHAPTER 14

P.H. Barry (School of Physiology and Pharmacology, University of New South Wales), S. Balasubramanian (School of Physiology and Pharmacology, University of New South Wales) and J.W. Lynch (Department of Physiology and Pharmacology, University of Queensland)
Contact
Professor P.H. Barry
School of Physiology and Pharmacology
University of New South Wales
Sydney, NSW 2052, Australia

CHAPTER 15

S.L. Sullivan
Contact
Dr S. Sullivan
National Institute on Deafness and other Communication Disorders
National Institutes of Health
5 Research Court
Rockville, MD 20850, USA,

CHAPTER 16

B. Key
Contact
Dr B. Key
Neurodevelopment Laboratory
Department of Anatomy and Cell Biology
University of Melbourne
Parkville, VIC 3052, Australia,

CHAPTER 17

G.A. Bell
Contact
Associate Professor G.A. Bell
Centre for ChemoSensory Research
University of New South Wales
Australian Technology Park
Sydney, NSW 1430, Australia

CHAPTER 18

A. Mackay-Sim
Contact
Associate Professor A. Mackay-Sim
School of Biomolecular and Biomedical Science
Griffith University
Brisbane, QLD 4111, Australia

CHAPTER 19

J. Atema
Contact
Professor J. Atema
Professor and Director
Boston University Maritime Program
Marine Biological Laboratory
Woods Hole, MA 02543, USA

CHAPTER 20

D.B. Hibbert
Contact
Professor D. Brynn Hibbert

Department of Analytical Chemistry
University of New South Wales
Sydney, NSW 2052, Australia

CHAPTER 21

D. Barnett
Centre for ChemoSensory Research,
University of New South Wales
& CRC International Food Manufacture
and Packaging Science
Contact
Associate Professor D. Barnett
Department of Analytical Chemistry
University of New South Wales
Sydney, NSW 2052, Australia,

CHAPTER 22

D.C. Levy and B. Naidoo
Contact
Dr D.C. Levy
Dept of Electrical Engineering
University of Sydney
Sydney, NSW 2006, Australia

CONTENTS

CHAPTER 1

THE SENSES: MEETING BIOLOGICAL NEEDS

D.M. STODDART

INTRODUCTION

The brain is fashioned to process information which flows to it from the outside world via the senses: sight, touch, hearing, taste and smell. Humans became essentially what they are today in the late Pliocene and early Pleistocene, about 2 million years ago. By that time they would have been quite recognisable as humans; little anatomical or physiological evolution has occurred since (Noble and Davidson, 1996), though the behaviour of modern humans is, on the whole, quite different from that of our Pleistocene relatives. The sense organs, together with their related operational physiology, and neural signal process signalling systems, are evolved structures which were moulded by natural selection operating on environmental selective pressures. Thus, when we smell 'Chanel No.5', taste the aroma of freeze-dried coffee volatiles, or listen to a Bach cantata, we do so with Palaeolithic noses, taste buds, and ears, designed by nature to serve the needs of hunter-gatherers of long ago. Our ancestors spent almost all of the last two million years as hunter-gatherers; the agrarian and intensely social lifestyle which typifies modern humans, developed just a second or two away from midnight on the 24 hour clock of human evolution. Our structure, brains and instinct enabled survival in a Pleistocene world. How we perceive the modern world is largely a product of our evolutionary past (Cosmides *et al.*, 1992).

The human sense organs did not all evolve at once. The evolutionary line that eventually gave rise to *Homo sapiens* can be traced back from the primates, through many branching dendrites to the earliest of the backboned animals, and further back to the single-celled origin of life itself. Animals that are anatomically simple, necessarily have simple sense organs, and single-celled animals have organelles which may have specialised functions. In evolutionary terms the most ancient of the senses is that which perceives chemical molecules — the so-called common chemical sense. Place an amoeba, taken from the bottom of a pond, in a glass dish, and watch it move around at random. Introduce a drop of vinegar at one side of the dish and you will notice the amoeba move away from this influence, seeking water of a neutral pH. The membrane surrounding the cell can detect this unfavourable environment, and it transmits this knowledge to the control centre in the nucleus. The result is a change in behaviour, every bit as profound as that which occurs when you pull down the sun visor in your car only to reveal a huntsman spider!

Of the senses we possess today, those of smell and taste are evolutionally the most ancient. Our world, and particularly our intellectual world, is one of sights and sounds bringing a continuous torrent of stimulation to our brains. With stereoscopic colour vision and acute hearing, humans are well-adapted for life on the open plains, where danger can be spotted at a distance, or heard as a leaf rustles under a pad or hoof. To lose the sense of sight or hearing is a disaster which few can overcome even with the use of complex modern electronic devices, but the loss of the sense of taste or smell generally causes little more than mild discomfiture. Is there a hierarchy of the senses? Will the sense of smell become a sensory equivalent of the human coccyx — a vestigial reminder of our evolutionary past? In this chapter I shall show that the sense of smell occupies a fundamental and fascinating place in the human psyche, and is far from redundant. It is anatomically simple — far simpler than the complex eye — but our understanding of its role in human biology is still fragmentary. This chapter will examine that role, and place it in a biological context.

THE SENSE OF SMELL

In physical terms the sense of smell consists of two tufts of spaghetti-like cilia lying high in the nasal cavity, which are connected to a special olfactory lobe of the brain. Unlike in the eye or the ear, where the receptor cells lie deeply buried behind many protective structures, the olfactory receptor cells of humans protrude into the outside world protected only by a thin layer of mucus. They are forward projections of the brain itself, and possibly the most exposed nervous tissue in the whole body. I shall leave a detailed description of the physiology and biochemistry of how the nose works to others, but suffice it to say that when odorant molecules are swept into the nasal cavity, they stimulate receptor sites on the spaghetti-like cilia. A wave of depolarisation flows down the axon of the receptor cell to the olfactory lobe of the brain. Just two or three synapses later and the signal, partially processed by various relay centres along the way, enters the so-called limbic system of the brain. In evolutionary terms the limbic system is the most ancient part of the brain; it is only in the higher mammals that the neocortex, or cerebral hemispheres, dominate. In fishes and other lower vertebrates the limbic system is known as the 'rhinencephalon' (or 'smell brain'), for so much of its activity is associated with the analysis of chemical molecules in the environment. In humans, the limbic system is thought to be the seat of emotion, with its many components interacting to control mood and temperament (Shepherd, 1983).

It is also the place where sexual behaviour and reproductive control is effected. Linked to the pituitary gland, or hypophysis, by a series of fine channels through which messenger substances can flow, the limbic system controls the pituitary gland and its production of the primary sex hormones: follicle stimulating hormone, and luteinising hormone. These two hormones stimulate the ovaries and the testes to mature and to produce their own sex hormones, oestrogen and testosterone.

Much is known of the role of smell in mammalian reproduction, and the interested reader is referred to some broad reviews for a comprehensive overview (eg Bronson, 1979; Stoddart, 1990). Odours are involved at almost all stages in mammalian reproductive biology: from initial attraction of the sexes and mate choice, to induction of oestrus, maintenance or termination of the pregnancy,