Rodents are the predominant experimental animals found in life-sciences research laboratories. The body temperature of a rodent is markedly affected by surgical, chemical, or environmental manipulation. Because temperature regulation is controlled essentially by a ''holistic'' regulatory system, meaning that its responses affect the activities of all other physiological and behavioral processes, it is clear that researchers working with rodents must be familiar with thermoregulatory physiology.

With the help of extensive data tables and figures, this book explains the key facets of rodent thermal physiology, including neurological control, metabolism, thermoregulatory effectors, core and brain temperatures, circadian rhythm, developmental patterns and aging, temperature acclimation, and gender and intraspecies variations. There is a novel chapter on the effects of trauma, toxic chemicals, and other factors. Mouse, gerbil, hamster, rat, and guinea pig are the rodents discussed. The book should therefore find use in government, academic, or industrial laboratories whose researchers are working with rodents.

Temperature regulation in laboratory rodents

Temperature regulation in laboratory rodents

CHRISTOPHER J. GORDON

Research Triangle Park, North Carolina

CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo

Cambridge University Press
The Edinburgh Building, Cambridge CB2 8RU, UK

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org
Information on this title: www.cambridge.org/9780521414265

First published 1993

A catalogue record for this publication is available from the British Library

Library of Congress Cataloguing in Publication data

Gordon, Christopher J.
Temperature regulation in laboratory rodents /
Christopher J. Gordon.

p. cm.
Includes bibliographical references.

ISBN 0-521-41426-1 (hardback)

1. Body temperature – Regulation. 2. Physiology, Comparative.
I. Title.

[DNLM: 1. Animals, Laboratory. 2. Body Temperature Regulation –
physiology. 3. Physiology, Comparative. 4. Rodentia – physiology.
QY 60.R6 G662c]

QP135.G57 1993
619′.93 – dc20
DNLM/DLC 92-49550
for Library of Congress CIP

ISBN 978-0-521-41426-5 hardback

Transferred to digital printing 2007

This publication was written by Christopher J. Gordon in his private capacity.
No official support or endorsement by the Environmental Protection
Agency or any other agency of the federal government is intended or
should be inferred.

Cambridge University Press
978-0-521-41426-5 - Temperature Regulation in Laboratory Rodents
Christopher J. Gordon
Frontmatter
More information

To my loving wife, Susie,
and children, Kevin and Karen

Contents

Preface

Why do we need a book devoted to the thermoregulatory characteristics of laboratory rodents? Such a book will be of obvious benefit to those involved in the study of thermal biology, but this book is also written to meet the needs of more readers than the relative handful of thermal biologists. One or more species of laboratory rodents are used predominantly by researchers in a variety of fields in the life sciences, including neural science, endocrinology, immunology, nutrition, and many others. The biological endpoints commonly measured in these fields would seem not to be related to thermoregulation. Yet manipulation of any one of these systems with surgical, pharmacological, and/or environmental procedures often leads to changes in the rodent's thermoregulation. Because temperature regulation is controlled essentially by a ''holistic'' regulatory system, meaning that its responses affect the activities of all other physiological and behavioral processes, it is clear that researchers working with rodents must be cognizant of thermoregulatory physiology.

Since completing my graduate work, I have found a need for a comprehensive source on the thermal physiology of laboratory rodents. Most other books on temperature regulation have focused on specific aspects of thermoregulation, such as fever, pharmacological control, exercise, and nonshivering thermogenesis. Other books have concentrated on specific mammalian species, particularly humans and the domesticated species that are of importance to agriculture. However, there are few sources that have examined the responses of a specific group of mammals such as the rodents. In 1971 the eminent Dr. J. S. Hart prepared a thorough monograph on the thermoregulatory characteristics of both wild and domesticated rodents (Hart, 1971). Although that is an excellent source for most thermal biologists, I have often thought that it does not necessarily address the needs of researchers whose primary interests are in fields other than thermoregulation. To address these needs, in 1990 I wrote a review on the thermal biology of the laboratory rat

(Gordon, 1990a). The popularity of that review, as judged from the number of reprint requests, was considerable. Because of the strong response to that review and encouragement from the editors of Cambridge University Press, I was convinced that a thorough comparative analysis of thermoregulatory responses in the commonly used laboratory rodents would be most useful.

The style of this book differs somewhat from the norm. I believe that a comparative book calls for a thorough presentation of the pertinent data from the literature. Because of the variability in some thermoregulatory parameters in a given species, I found it necessary to tabulate data from a number of laboratories to facilitate comparison. The tables allow the reader to quickly assess and compare the thermoregulatory characteristics of a particular species. Moreover, it is hoped that voids in the data presented in these tables will indicate where future research should be directed. In preparing the illustrations, I sought, whenever possible, to show the responses of two or more rodent species. The level of detail in this book was one of my greatest concerns. With over 700 references, it should be obvious that I have tried to make the coverage as extensive as possible without exceeding the publisher's space limitation. However, in the course of doing the research for this book it is likely that I overlooked some pertinent papers. To the authors of those papers I apologize, and I hope that they will inform me of my oversights.

I have attempted to write this text at a level that should meet the needs of researchers with a minimum background of upper-level undergraduate courses in physiology and/or related fields. The book covers the physiological and behavioral responses of the principal laboratory rodents: mouse, gerbil, hamster, rat, and guinea pig. Although recent molecular studies have suggested that the guinea pig is not a true rodent, its thermoregulatory responses are considered here along with those of other rodent species. What I, and many other researchers, consider to be the most pertinent facets of thermoregulatory physiology are covered: neurological control, metabolism, homeostasis of body and brain temperatures, stress, motor effectors, growth and development, temperature acclimation, and intraspecies and gender differences. The final chapter deals with a novel aspect not commonly presented in other texts, but nonetheless crucial to today's researcher: the effects of adverse perturbations, including hypoxia, chemical toxicity, and trauma, on thermoregulation.

Acknowledgments

This book would not have been possible if not for the invaluable training and guidance I received from my postgraduate advisors: Dr. J. Homer Ferguson, formerly of the University of Idaho, and Dr. James E. Heath of the University of Illinois, Urbana-Champaign. They have been inspirational in stimulating my interest in environmental and comparative physiology. I am appreciative of the efforts of the following colleagues who graciously provided critiques of chapters in the book: Drs. W. C. Duncan, A. H. Rezvani, D. B. Miller, W. P. Watkinson, R. Refinetti, S. C. Wood, and E. Berman. Although they are too numerous to name, I would like to thank all the thermal physiologists who kindly furnished me with up-to-date papers from their laboratories for the preparation of the book. I am also grateful to Drs. K. Zylan and R. Smith of Cambridge University Press for providing invaluable editorial assistance. Finally, I thank all the members of my family for their abiding support in this endeavor.

List of abbreviations

ATP, adenosine triphosphate
AVA, arterial-venous anastomosis
AVP, arginine vasopressin
BAT, brown adipose tissue
BBB, blood-brain barrier
BMR, basal metabolic rate
C′, whole-body thermal conductance
CIVD, cold-induced vasodilation
CNS, central nervous system
CT_{max}, critical thermal maximum
CT_{min}, critical thermal minimum
CTR, circadian temperature rhythm
DIT, diet-induced thermogenesis
ECG, electrocardiogram
EDT, elevated defended temperature
EEG, electroencephalogram
EHL, evaporative heat loss
EMG, electromyogram
EP, endogenous pyrogen
EWL, evaporative water loss
F344, Fischer 344
FFAs, free fatty acids
FSH, follicle-stimulating hormone
GDP, guanosine diphosphate
IL-1, interleukin 1
IR, infrared
LCT, lower critical ambient temperature
LD_{50}, lethal dose for 50% mortality
LE, Long-Evans
LH, luteotropic hormone
LOMR, least observed metabolic rate
LPS, lipopolysaccharide
M (MR), metabolic rate
MAP, mean arterial pressure
MMR, maximum metabolic rate
MOMR, minimum observed metabolic rate
NE, norepinephrine (noradrenaline)
NPRQ, nonprotein respiratory quotient
NST, nonshivering thermogenesis
OVLT, organovasculosum lamina terminalis
PGE_n, prostaglandin E_1 or E_2
PMR, peak metabolic rate
POAH, preoptic area/anterior hypothalamus
PS, paradoxical sleep
PVMT, peripheral vasomotor tone
RF, radio frequency
RMR, resting metabolic rate
RQ, respiratory quotient
SA, surface area
SCN, suprachiasmatic nucleus
SD, Sprague-Dawley
SHR, spontaneously hypertensive rat
SMR, standard metabolic rate
SWS, slow-wave sleep

Selected T_a, selected ambient temperature
T_a, ambient temperature
TBTS, total-body thermosensitivity
T_b, body temperature (core temperature)
T_c, core temperature
T_h, hypothalamic temperature
T_{set}, set-point temperature
T_3, triiodothyronine
T_4, thyroxine
T5′ D, thyroxine 5′-deiodinase
TNZ, thermoneutral zone
UCP, uncoupling protein
UCT, upper critical ambient temperature
WAT, white adipose tissue