Integration in Respiratory Control

From Genes to Systems
Contents

Preface ......................................................... v
Erratum .................................................... xxxi

Part I Historical and Future Perspectives of the Control of Breathing

1 History of Measuring O₂ and CO₂ Responses .......................... 3
John W. Severinghaus

2 J.S. Haldane and Some of His Contributions to Physiology .......... 9
John B. West

3 Control of the Exercise Hyperpnea: The Unanswered Question .... 16
Brian J. Whipp

Part II Oxygen Sensing and the Carotid Body

4 A Peripheral Oxygen Sensor Provides Direct Activation of an Identified Respiratory CPG Neuron in Lymnaea .................. 25
Harold J. Bell, Takuya Inoue and Naweed I. Syed

5 Environmental Hyperoxia and Development of Carotid Chemoafferent Function ................................................. 30
Gerald Bisgard, Julie Wenninger, Zunyi Wang and E. Burt Olson, Jr.

6 HSP70 Reduces Chronic Hypoxia-Induced Neural Suppression via Regulating Expression of Syntaxin ....................... 35
Guanghe Fei, Conghui Guo, Hong-Shuo Sun and Zhong-Ping Feng
7 Effect of Systemic Administration of the Nitric Oxide Synthase Inhibitor L-NMMA on the Human Ventilatory Response to Hypoxia .................................................. 41
Kojiro Ide, Matthew Worthley, Todd Anderson and Marc J. Poulin

8 Effects of Volatile Anesthetics on Carotid Body Response to Hypoxia in Animals .................................................. 46
Jaideep J. Pandit and Kevin O’Gallagher

9 Mutation of the von Hippel-Lindau Gene Alters Human Cardiopulmonary Physiology ........................................... 51

10 Intravenous Endothelin-1 and Ventilatory Sensitivity to Hypoxia in Humans .................................................. 57
Nick P. Talbot, George M. Balanos, Peter A. Robbins and Keith L. Dorrington

11 Key Roles for AMP-activated Protein Kinase in the Function of the Carotid Body? ................................. 63
Christopher N. Wyatt, Selina A. Pearson, Prem Kumar, Chris Peers, D. Grahame Hardie and A. Mark Evans

12 Stimulatory Actions of Pituitary Adenylate Cyclase-Activating Polypeptide (PACAP) in Rat Carotid Glomus Cells ........................................... 69
Fenglian Xu, Frederick W. Tse and Amy Tse

13 Post-hypoxic Unstable Breathing in the C57BL/6J Mouse: Effects of Acetazolamide ........................................... 75
Motoo Yamauchi, Jesse Dostal and Kingman P. Strohl

Part III Respiratory Rhythm Generation

14 Catecholaminergic Modulation of the Respiratory Rhythm Generator in the Isolated Brainstem–Spinal Cord Preparation from Neonatal Rat ........................................... 83
Akiko Arata and Morimitsu Fujii

15 What Role Do Pacemakers Play in the Generation of Respiratory Rhythm? ........................................... 88
Christopher A. Del Negro, Ryland W. Pace and John A. Hayes
16 Pre-Bötzinger Complex Neurokinin-1 Receptor Expressing Neurons in Primary Cell Culture. .......................... 94
Sheree M. Johnson

17 Belt-and-Suspenders as a Biological Design Principle. .......................... 99
Nicholas M. Mellen

18 Two Modes of Respiratory Rhythm Generation in the Newborn Rat Brainstem- Spinal Cord Preparation. .... 104
Hiroshi Onimaru and Ikuo Homma

19 Possible Roles of the Weakly Inward Rectifying K+ Channel Kir4.1 (KCNJ10) in the Pre-Bötzinger Complex .... 109
Nestoras Papadopoulos, Stefan M. Winter, Kai Härtel,
Melanie Kaiser, Clemens Neusch and Swen Hülsmann

20 Contribution of Pacemaker Neurons to Respiratory Rhythms Generation in vitro .................................. 114
Fernando Peña

21 Emergent Bursting in Small Networks of Model Conditional Pacemakers in the pre-Bötzinger Complex .... 119
Jonathan E. Rubin

Part IV Genes and Development

22 Brain Nuclei Controlling the Spinal Respiratory Motoneurons in the Newborn Mouse .......................... 127
Michelle Bévengut, Patrice Coulon and Gérard Hilaire

23 Superoxide Dismutase-1 Influences the Timing and Post-hypoxic Stability of Neonatal Breathing ............ 133
Kevin J. Cummings, Dan Kalf, Sherry Moore, B. Joan Miller,
Frank R. Jirik and Richard J.A. Wilson

24 Neurodevelopmental Abnormalities in the Brainstem of Prenatal Mice Lacking the Prader-Willi Syndrome Gene Necdin. .................................. 139
Silvia Pagliardini, Jun Ren, Rachel Wevrick and John J. Greer

25 Consequences of Prenatal Exposure to Diazepam on the Respiratory Parameters, Respiratory Network Activity and Gene Expression of α1 and α2 Subunits of GABA Receptor in Newborn Rat. .................. 144
Nathalie Picard, Stéphanie Guenin, Yolande Perrin,
Gérard Hilaire and Nicole Larnicol
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Modulation of Perinatal Respiratory Rhythm by GABA&lt;sub&gt;α&lt;/sub&gt;- and Glycine Receptor-mediated Chloride Conductances</td>
<td>149</td>
</tr>
<tr>
<td></td>
<td>Jun Ren and John J. Greer</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Laryngeal Stimulation by an Acid Solution in the Pre-term Lamb</td>
<td>154</td>
</tr>
<tr>
<td></td>
<td>Marie St-hilaire, Nathalie Samson, Charles Duvareille and Jean-Paul Praud</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Necdin Gene, Respiratory Disturbances and Prader-Willi Syndrome</td>
<td>159</td>
</tr>
<tr>
<td></td>
<td>Sébastien Zanella, Magali Barthelemy, Françoise Muscatelli, and Gérard Hilaire</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Part V</strong> Models of Gas Exchange</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Quantitative Analysis of the Oxygen Transfer in the Human Acinus</td>
<td>167</td>
</tr>
<tr>
<td></td>
<td>Marcel Filoche, André A. Moreira, José S. Andrade, Jr. and Bernard Sapoval</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Role of Diffusion Screening in Pulmonary Diseases</td>
<td>173</td>
</tr>
<tr>
<td></td>
<td>Bernard Sapoval and Marcel Filoche</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>A dp/dt Method to Assess Dynamic Properties of Lung Mechanoreceptors</td>
<td>179</td>
</tr>
<tr>
<td>32</td>
<td>Pulmonary Gas Exchange in Anatomically-Based Models of the Lung</td>
<td>184</td>
</tr>
<tr>
<td></td>
<td>Annalisa Swan, Peter Hunter and Merryn Tawhai</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Multi-scale Models of the Lung Airways and Vascular System</td>
<td>190</td>
</tr>
<tr>
<td></td>
<td>Merryn H. Tawhai and Kelly S. Burrowes</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Modeling Structure-Function Interdependence of Pulmonary Gas Exchange</td>
<td>195</td>
</tr>
<tr>
<td></td>
<td>Ewald R. Weibel</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Part VI</strong> Plasticity and Adaptation</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Ventilatory Control during Intermittent High-Intensity Exercise in Humans</td>
<td>203</td>
</tr>
<tr>
<td></td>
<td>Andrew J. Cathcart, Anthony P. Turner, Christopher Butterworth, Matthew Parker, John Wilson and Susan A. Ward</td>
<td></td>
</tr>
<tr>
<td>Page</td>
<td>Title</td>
<td>Authors</td>
</tr>
<tr>
<td>------</td>
<td>----------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>37</td>
<td>Phase Relations Between Rhythmical Movements and Breathing in Wind Instrument Players</td>
<td>Dietrich Ebert and Wieland Kaerger</td>
</tr>
<tr>
<td>38</td>
<td>The Effect of Two Different Intermittent Hypoxia Protocols on Ventilatory Responses to Hypoxia and Carbon Dioxide at Rest</td>
<td>Michael Koehle, William Sheel, William Milsom and Donald McKenzie</td>
</tr>
<tr>
<td>39</td>
<td>Respiratory Long-Term Facilitation: Too Much or Too Little of a Good Thing?</td>
<td>Safrzaaz Mahamed and Gordon S. Mitchell</td>
</tr>
<tr>
<td>40</td>
<td>Contribution of Endothelin-1 and Endothelin A and B Receptors to the Enhanced Carotid Body Chemosensory Responses Induced by Chronic Intermittent Hypoxia</td>
<td>Sergio Rey, Rodrigo Del Rio and Rodrigo Iturriaga</td>
</tr>
<tr>
<td>41</td>
<td>Intermittent Hypoxia Induces Respiratory Long-Term Facilitation in Postnatal Rats</td>
<td>Arash Tadjalli, James Duffin and John Peever</td>
</tr>
<tr>
<td>42</td>
<td>Respiratory Control, Respiratory Sensations and Cycling Endurance After Respiratory Muscle Endurance Training</td>
<td>Samuel Verges, Urs Kruttli, Bernhard Stahl, Ralf Frigg and Christina M. Spengler</td>
</tr>
<tr>
<td>43</td>
<td>Non-dimensional Quantification of the Interactions Between Hypoxia, Hypercapnia and Exercise on Ventilation in Humans</td>
<td>H.E. Wood, M. Fatemian and P.A. Robbins</td>
</tr>
<tr>
<td>44</td>
<td>Elevated Body Temperature Exaggerates Laryngeal Chemoreflex Apnea in Decerebrate Piglets</td>
<td>Luxi Xia, Tracey Damon, J.C. Leiter and Donald Bartlett, Jr.</td>
</tr>
</tbody>
</table>

Part VII Neuromodulation

<table>
<thead>
<tr>
<th>Page</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>46</td>
<td>Control of Genioglossus Muscle by Sleep State-Dependent Neuromodulators</td>
<td>Richard L. Horner</td>
</tr>
<tr>
<td>47</td>
<td>Significance of Multiple Neurochemicals that Regulate Respiration</td>
<td>Paul M. Pilowsky, Qi-Jian Sun, Tina Lonergan, John M. Makeham, Maryam Seyedabadi, Todd A. Verner and Ann K. Goodchild</td>
</tr>
<tr>
<td>49</td>
<td>Major Components of Endogenous Neurotransmission Underlying the Discharge Activity of Hypoglossal Motoneurons in vivo</td>
<td>Edward J. Zuperku, Ivo F. Brandes, Astrid G. Stucke, Antonio Sanchez, Francis A. Hopp and Eckehard A. Stuth</td>
</tr>
<tr>
<td></td>
<td>Part VIII Comparative Aspects</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Control of Ventilation in Diving Birds</td>
<td>Patrick J. Butler and Lewis G. Halsey</td>
</tr>
<tr>
<td>51</td>
<td>Evolutionary Trends in Respiratory Mechanisms</td>
<td>William K. Milsom</td>
</tr>
<tr>
<td></td>
<td>Part IX Central Chemosensitivity</td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>A Computer Model of Mammalian Central CO₂ Chemoreception</td>
<td>Mykyta Chernov, Robert W. Putnam and J.C. Leiter</td>
</tr>
<tr>
<td>53</td>
<td>A Mathematical Model of pH Regulation in Central CO₂-Chemoreception</td>
<td>Juan M. Cordovez, Chris Clausen, Leon C. Moore and Irene C. Solomon</td>
</tr>
<tr>
<td>54</td>
<td>Plasticity in the Brain: Influence of Bilateral Carotid Body Resection (bCBR) on Central CO₂ Sensitivity</td>
<td>Albert Dahan, Elise Sarton and Luc Teppema</td>
</tr>
<tr>
<td>55</td>
<td>Glial Modulation of CO₂ Chemosensory Excitability in the Retrotrapezoid Nucleus of Rodents</td>
<td>Joseph S. Erlichman, Robert W. Putnam and J.C. Leiter</td>
</tr>
</tbody>
</table>
56  The Carotid Chemoreceptors are a Major Determinant of Ventilatory CO₂ Sensitivity and of PaCO₂ During Eupneic Breathing ......................................................... 322
  Hubert V. Forster, Paul Martino, Matt Hodges, Katie Krause, Josh Bonis, Suzanne Davis and L. Pan
57  The Retrotrapezoid Nucleus and Central Chemoreception ............. 327
  Patrice G. Guyenet, Douglas A. Bayliss, Daniel K. Mulkey, Ruth L. Stornetta, Thiago S. Moreira and Ana T. Takakura
58  The Chemosensitive Response of Neurons from the Locus Coeruleus (LC) to Hypercapnic Acidosis with Clamped Intracellular pH ................................................................. 333
  Lynn K. Hartzler, Jay B. Dean and Robert W. Putnam
59  CO₂-sensitivity of GABAergic Neurons in the Ventral Medullary Surface of GAD67-GFP Knock-in Neonatal Mice ...... 338
  Junya Kuribayashi, Shigeki Sakuraba, Yuki Hosokawa, Eiki Hatori, Miki Tsujita, Junzo Takeda, Yuchio Yanagawa, Kunihiko Obata and Shun-ichi Kuwana
60  Multiple Central Chemoreceptor Sites: Cell Types and Function in vivo ............................................................... 343
  Gene Nattie and Aihua Li
61  Intrinsic Chemosensitivity of Individual Nucleus Tractus Solitarius (NTS) and Locus Coeruleus (LC) Neurons from Neonatal Rats ................................................................. 348
  Nicole L. Nichols, Lynn K. Hartzler, Susan C. Conrad, Jay B. Dean and Robert W. Putnam
62  Chemosensitive Neuronal Network Organization in the Ventral Medulla Analyzed by Dynamic Voltage-Imaging ................ 353
  Yasumasa Okada, Shun-ichi Kuwana, Haruko Masumiya, Naofumi Kimura, Zibin Chen and Yoshitaka Oku

Part X  Brainstem Mechanisms Underlying Cardio-Respiratory Control

63  The Effects of a Respiratory Acidosis on Human Heart Rate Variability ............................................................... 361
  S.J. Brown and R. Howden
64  Neurokinin-1 Receptor Activation in the Bötzinger Complex Evokes Bradypnea and is Involved in Mediating the Hering-Breuer Reflex ................................................... 366
  Angelina Y. Fong and Jeffrey T. Potts
65 Brainstem Catecholaminergic Neurons Modulate both Respiratory and Cardiovascular Function. 371
Aihua Li, Laura Emond and Eugene Nattie

66 Responses of Brainstem Respiratory Neurons to Activation of Midbrain Periaqueductal Gray in the Rat 377
Hari Subramanian, Zheng-Gui Huang and Ron Balnave

67 Computational Model of TASK Channels and PKC-Pathway Dependent Serotonergic Modulatory Effects in Respiratory-Related Neurons. 382
Tzu-Hsin B. Tsao and Robert J. Butera

68 Modulation of Hering-Breuer Reflex by Ventrolateral Pons 387
Hui Wang, Heng Zhang, Gang Song and Chi-Sang Poon

69 Respiratory Network Complexity in Neonatal Rat in vivo and in vitro 393
Hui Jing Yu, Xinnian Chen, Ryan M. Foglyano, Christopher G. Wilson and Irene C. Solomon

Part XI Multifunctional and Reconfiguring Networks

70 Fast Oscillatory Rhythms in Inspiratory Motor Discharge: A Mathematical Model 401
Xinnian Chen, Ki H. Chon and Irene C. Solomon

71 Burst-to-Burst Variability in Respiratory Timing, Inspiratory-Phase Spectral Activity, and Inspiratory Neural Network Complexity in Urethane-Anesthetized C57BL/6 Mice in vivo 407
Hyun Hye Chun, Evan T. Spiegel and Irene C. Solomon

72 Effects of Hypercapnia on Non-nutritive Swallowing in Newborn Lambs 413
Charles Duvareille, Nathalie Samson, Marie St-Hilaire, Philippe Micheau, Véronique Bournival and Jean-Paul Praud

73 CPAP Inhibits Non-nutritive Swallowing Through Stimulation of Bronchopulmonary Receptors 418
Nathalie Samson, Charles Duvareille, Marie St-Hilaire, Véronique Clapperton and Jean-Paul Praud

74 Glutamatergic Neurotransmission is Not Essential for, but Plays a Modulatory Role in, the Production of Gasping in Arterially-Perfused Adult Rat 423
Kelly A. Warren and Irene C. Solomon
Part XII Clinical Perspectives: Modeling and Control of Breathing
(i.e., Sleep Apnea)

75 Potential Mechanism for Transition Between Acute Hypercapnia During Sleep to Chronic Hypercapnia During Wakefulness in Obstructive Sleep Apnea
Kenneth I. Berger, Robert G. Norman, Indu Ayappa, Beno W. Oppenheimer, David M. Rapoport and Roberta M. Goldring

431

76 Biochemical Control of Airway Motor Neurons During Rapid Eye Movement Sleep.
Patricia L. Brooks and John H. Peever

437

77 Prediction of Periodic Breathing at Altitude
Keith Burgess, Katie Burgess, Prajan Subedi, Phil Ainslie, Zbigniew Topor and William Whitelaw

442

78 A Negative Interaction Between Central and Peripheral Respiratory Chemoreceptors May Underlie Sleep-Induced Respiratory Instability: A Novel Hypothesis
Trevor A. Day and Richard J.A. Wilson

447

79 Ventilatory Response to Hypercapnia in Pre-menopausal and Post-menopausal Women
Chantel T. Debert, Kojiro Ide and Marc J. Poulin

452

80 Oxidative Stress Impairs Upper Airway Muscle Endurance in an Animal Model of Sleep-Disordered Breathing
Mark Dunleavy, Aidan Bradford and Ken D. O’Halloran

458

81 Ventilatory and Blood Pressure Responses to Isocapnic Hypoxia in OSA Patients
Glen E. Foster, Patrick J. Hanly, Michele Ostrowski and Marc J. Poulin

463

82 Modeling of Sleep-Induced Changes in Airway Function: Implication for Nocturnal Worsening of Bronchial Asthma
Musa A. Haxhiu, Prabha Kc, Kannan V. Balan, Christopher G. Wilson and Richard J. Martin

469

83 The Effects of Wakefulness State on the Temporal Characteristics of Ventilatory Variables in Man

475
84 Cerebral Blood Flow and Ventilatory Sensitivity to CO₂ Measured with the Modified Rebreathing Method .......... 480
Jaideep J. Pandit, Ravi M. Mohan, Nicole D. Paterson and M.J. Poulin

85 Naloxone Reversal of Opioid-Induced Respiratory Depression with Special Emphasis on the Partial Agonist/Antagonist Buprenorphine ......................... 486
Elise Sarton, Luc Teppema and Albert Dahan

86 The Pulse Oxygen Saturation: Inspired Oxygen Pressure (SpO₂:P₁O₂) Diagram: Application in the Ambulatory Assessment of Pulmonary Vascular Disease ......................... 492
Neil M. Skjodt, Christian Ritz and Dilini Vethanayagam

87 Hypocapnia and Airway Resistance in Normal Humans ............. 497
Craig D. Steinback, William A. Whitelaw and Marc J. Poulin

88 Disturbances of Breathing in Rett Syndrome: Results from Patients and Animal Models ..................... 503
Georg M. Stettner, Peter Huppke, Jutta Gärtner, Diethelm W. Richter and Mathias Dutschmann

89 NHE3 in the Human Brainstem: Implication for the Pathogenesis of the Sudden Infant Death Syndrome (SIDS)? ......................... 508
Martin Wiemann, Stilla Frede, Frank Tschentscher, Heidrun Kiwull-Schöne, Peter Kiwull, Dieter Bingmann, Bernd Brinkmann and Thomas Bajanowski

90 The Ventilatory Response to Exercise Does Not Differ Between Obese Women With and Without Dyspnea on Exertion ..................... 514
Helen E. Wood, Trisha L. Semon, Laurie A. Comeau, Belinda Schwartz, Rebecca M. MacDougall, Marilyn N. Klocko and Tony G. Babb

Author Index ....................................................... 519

Subject Index ....................................................... 537