

NURSERY REARING OF NONHUMAN  
PRIMATES IN THE 21<sup>st</sup> CENTURY

## **DEVELOPMENTS IN PRIMATOLOGY: PROGRESS AND PROSPECTS**

### **Series Editor:**

Russell H. Tuttle

University of Chicago, Chicago, Illinois

---

This peer-reviewed book series will meld the facts of organic diversity with the continuity of the evolutionary process. The volumes in this series will exemplify the diversity of theoretical perspectives and methodological approaches currently employed by primatologists and physical anthropologists. Specific coverage includes: primate behavior in natural habitats and captive settings; primate ecology and conservation; functional morphology and developmental biology of primates; primate systematics; genetic and phenotypic differences among living primates; and paleoprimatology.

### **ALL APES GREAT AND SMALL**

#### **VOLUME I: AFRICAN APES**

Edited by Birute M.F. Galdikas, Nancy Erickson Briggs, Lori K. Sheeran,  
Gary L. Shapiro and Jane Goodall

### **THE GUENONS: DIVERSITY AND ADAPTATION IN AFRICAN MONKEYS**

Edited by Mary E. Glenn and Marina Cords

### **ANIMAL MINDS, HUMAN BODIES**

By W.A. Hillix and Duane Rumbaugh

### **COMPARATIVE VERTEBRATE COGNITION**

Edited by Lesley J. Rogers and Gisela Kaplan

### **ANTHROPOID ORIGINS: NEW VISIONS**

Edited by Callum F. Ross and Richard F. Kay

### **MODERN MORPHOMETRICS IN PHYSICAL ANTHROPOLOGY**

Edited by Dennis E. Slice

### **BEHAVIORAL FLEXIBILITY IN PRIMATES: CAUSES AND CONSEQUENCES**

By Clara B. Jones

### **NURSERY REARING OF NONHUMAN PRIMATES IN THE 21st CENTURY**

Edited by Gene P. Sackett, Gerald C. Ruppenthal and Kate Elias

# NURSERY REARING OF NONHUMAN PRIMATES IN THE 21st CENTURY

Edited by

**Gene P. Sackett**

*Washington National Primate Research Center  
University of Washington  
Seattle, WA, USA*

**Gerald C. Ruppenthal**

*Washington National Primate Research Center  
University of Washington  
Seattle, WA, USA*

**Kate Elias**

*Washington National Primate Research Center  
University of Washington  
Seattle, WA, USA*

 Springer

**Gene P. Sackett**

Washington National Primate Research Center  
University of Washington  
Seattle, WA  
USA

**Gerald C. Ruppenthal**

Washington National Primate Research Center  
University of Washington  
Seattle, WA  
USA

**Kate Elias**

Washington National Primate Research Center  
University of Washington  
Seattle, WA  
USA

Library of Congress Control Number: 2005924427

ISBN-10: 0-387-25632-6

ISBN-13: 978-0387-25632-0

Printed on acid-free paper.

© Springer Science+Business Media, Inc., 2006

All rights reserved. This work may not be translated or copied in whole or in part without the written permission of the publisher (Springer Science+Business Media, Inc., 233 Spring Street, New York, NY 10013, USA), except for brief excerpts in connection with reviews or scholarly analysis. Use in connection with any form of information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed is forbidden.

The use in this publication of trade names, trademarks, service marks, and similar terms, even if they are not identified as such, is not to be taken as an expression of opinion as to whether or not they are subject to proprietary rights.

Printed in the United States of America. (BS/EB)

9 8 7 6 5 4 3 2 1

[springeronline.com](http://springeronline.com)

## PREFACE: OUR HISTORICAL NOTE

It was 1970 when Gerry Ruppenthal and Jim Sackett moved from the University of Wisconsin in Madison to the University of Washington in Seattle. In Wisconsin, Gerry had been working for Harry and Margaret Harlow for over a decade and supervised many of their classic studies of the 1960s. Jim was an associate professor in the psychology department and was in his seventh year of primate research in what is now the Harlow Primate Laboratory. Collectively, we were experienced in studying infant, juvenile, and adult rhesus macaques that had been reared under a variety of captive conditions. Many of these monkeys had been reared in the Harlow Primate Laboratory nursery.

We were brought to Seattle by the Regional Primate Research Center (PC) and the Child Development and Mental Retardation Center (CDMRC), now called the Center on Human Development and Disability (CHDD). Gerry was a research scientist with both NIH-funded centers, while Jim was a professor in the psychology department, a PC core staff member, and PI of a CDMRC 3-year new program grant. Harry Harlow generously allowed us to take a great deal of equipment from Wisconsin—cages, rearing units, developmental testing apparatus, and recording devices. If he had paid more attention, we probably would not have gotten away with as much “loot,” but the University of Wisconsin and NIH approved it all. With some additional local start-up funds and a really large amount of space, we started a primate nursery and organized a developmental rearing room and some testing rooms. Our equipment and methods were essentially identical to those used for over 15 years in the Wisconsin laboratory.

Our initial goal was to replicate the effects of isolation and peer rearing found in rhesus macaques in the classic Harlow work. We wanted to do this to learn why male rhesus macaques were affected so much more than females by asocial rearing. Because the PC breeding colony consisted of pigtailed macaques (*Macaca nemestrina*), we needed to demonstrate that they responded like rhesus macaques with the same sex and rearing differences before going on to mechanistic studies of possible causes. Not only did we fail to find sex differences following asocial rearing of pig-tails, we also failed to find the same devastating effects of isolation rearing on postrearing social and exploratory behavior. This convinced us that gene–environment interactions were to be expected in assessing acute and chronic effects of rearing conditions on behavior, and probably also on physiology. This theme, in one guise or another, will be found through much of this book.

Our nursery is situated adjacent to the University Hospital, just below the human neonatal intensive care unit, and word soon got out that it was possible to study monkey pregnancy, neonates, and infants in a primate nursery located almost next to one’s own office and laboratory. This led to requests to use our facilities by a number of medical researchers, especially a group of neonatologists who were studying lung function in premature newborns. With their help, our nursery came to include a primate neonatal intensive care unit. Also, rather than euthanizing newborns that were premature or low birth weight, ill, had life-threatening birth defects, or whose mothers were ill, wounded, or dead, the PC breeding colony managers began sending such at-risk neonates and young infants to our nursery, initiating an “Infant-Save” program that continues to this day.

By 1971 it was obvious that our nursery was a valuable resource for scientists who were interested in prenatal, perinatal, and infancy studies. As both the PC and CDMRC 5-year core grants were being written for renewal in 1972, we convinced the directors of both centers to include a proposal to support a nursery facility, the Infant Primate Research Laboratory (IPRL). In what appears to be a unique relationship among NIH-supported university centers, our proposal was funded by both core grant requests and we have shared this funding ever since.

From our point of view, the IPRL has had two main purposes. The first has been to use primate models to study important human medical

and behavioral problems. This has been the major reason for continued grant success in the CDMRC arm of our endeavors. Equally important, we have spent much of our PC-based resources studying primate medicine and husbandry issues related to breeding, pregnancy and fetal development, hand-rearing methods, and methods of assessing growth, physiology, and behavioral development. Our NIH-supported efforts and those of many other researchers and veterinarians led to the then state-of-the-art publication, *Nursery Care of Nonhuman Primates*, edited by Gerry Ruppenthal and Dorothy Reese, published by Plenum in 1979.

Although much of that book is still relevant today, methods of nursery care, methods of testing, and types of experimental and husbandry problems have changed markedly since 1979. This has resulted in new challenges involving nursery rearing of monkeys with many types of naturally occurring and experimentally induced medical and developmental conditions. New challenges have arisen through changes in attitudes toward animal testing and resulting changes in standards of animal care involving concerns for both the physical and psychological well-being of captive primates. One goal of this book is to describe how these challenges have been met over the past 25 years. The other goal is to show how changes in rearing methods have altered for the better the developmental outcomes of nursery rearing, at least in some species and some facilities. We hope that our story, begun in the 1979 book and continued in the current one, will produce a more realistic view of nursery rearing and its effects than that claimed by opponents of nursery rearing on the basis of antiquated methods now used by only a few facilities or individuals.

This book originated in a workshop of the same name, *Nursery Rearing of Nonhuman Primates in the 21st Century*, held in 2002 at the Oklahoma City meeting of the American Society of Primatologists. All of the workshop presenters are represented, in addition to a number of authors recruited to present important topics not covered in the workshop. We are grateful to all our contributors. We had hoped to include either a section or a CD of basic growth and health data for nursery-compared with mother-reared primates that would serve as normative comparison data for current and future research. Unfortunately, we were able to collect such data on only a few species, although they are ones that are frequently nursery reared in current work. Data on health sta-

tistics are included in the final section as an example of basic data that can, and probably should, be collected and disseminated for all laboratory and zoo nursery-reared primate species.

Over the decades our work has involved a large number of students, scientists, health workers, technical personnel, and administrators. They are too numerous to list here, but we must thank our earliest University of Washington students, Dick Holm, Sharon Ramey (nee Landesman), and Jon Lewis, who helped us start the IPRL in both concept and fact. Carol Fahrenbruch, Sherry Savage, Colleen Walker-Gelatt, and Gary Bartram provided invaluable effort in developing and implementing our rearing and developmental testing methods. Without the support of our Primate Center directors, especially Orville Smith, and our CDMRC directors, especially Irvin Emanuel and Michael Guralnick, we would have had quite different careers. We are also grateful to the NIH for its continued support from the National Center for Research Resources, grant RR00166, and NICHHD Mental Retardation Branch, grant HD02274.

*Gene P. (Jim) Sackett*

*Gerald C. Ruppenthal*

*Kate Elias*

Seattle and Pittsburgh, 2004



# CONTENTS

<b>Preface: Our Historical Note</b>	v
<b>Contributors</b>	xxiii
<b>Introduction</b>	xxvii
<b>Section 1</b>	1
<b>Introduction to Section 1: The History of Nursery Rearing and a Glimpse into the Future</b>	3
<b>1 The Effects of Rearing Experiences: The Early Years</b> <i>Melinda A. Novak and Gene P. Sackett</i>	5
1. Historical Perspective	5
2. Early Rearing Experience Paradigm: The Study of Plasticity	7
2.1. Total Isolation Rearing	7
2.2. Surrogate-Only Rearing	9
2.3. Partial Isolation Rearing	9
2.4. Peer-Only Rearing	10
2.5. Surrogate-Peer Rearing	11
2.6. Mother-Only Rearing	12
3. Reversibility of Negative Rearing Outcomes	13
3.1. Agemate Therapy	13
3.2. Adaptation Therapy	14
3.3. Attachment Therapy	14

3.4. Training Therapy	14
3.5. Younger-Monkey Therapy	15
4. From the Past to the Present	16
References	16
<b>2 The Changing Role of Hand Rearing in Zoo-Based Primate Breeding Programs</b>	<b>21</b>
<i>Ingrid Porton and Kelli Niebruegge</i>	
1. The History of Hand-Rearing Primates in Zoos	21
2. Resocialization Goals and Techniques	24
3. Evaluation of Hand-Reared Primates	26
4. Summary	28
References	29
<b>3 Animal Welfare Regulations and Nursery Rearing</b>	<b>33</b>
<i>Carolyn M. Crockett</i>	
1. History and Overview of Regulations	33
2. Current USDA Regulations Pertaining to Infants	36
3. USDA Draft Policy and ASP Comments	39
4. NRC-ILAR Volume on Psychological Well-Being of Nonhuman Primates	40
5. Guide for the Care and Use of Laboratory Animals	42
6. AAALAC International	43
7. The American Zoo and Aquarium Association (AZA)	43
8. International Regulations	44
9. Recommendations	44
10. Conclusions	46
References	47
<b>4 Data Management for the Nonhuman Primate Nursery</b>	<b>49</b>
<i>James C. Ha and Arthur E. Davis</i>	
1. Introduction	49
1.1. Historical Standards	51
2. Modern Issues and Approaches	53
3. Animal Record Contents	54
4. Quality Control	57

5. New Techniques for Data Collection, Storage, and Retrieval	61
6. Conclusions	63
References	64
<b>5 Very Early Rearing Experience: Rationale and Methodologies for Studying Prenatal Development in Nonhuman Primates</b>	<b>65</b>
<i>Matthew Francis Stuart Xavier Novak</i>	
1. Introduction	65
2. Methodologies and Datasets	67
2.1. Happenstance and Evolutionary Byproduct	67
2.2. Terminal Methodologies	68
2.3. Indirect Methodologies	71
2.4. Selective Breeding Studies	76
2.5. Direct Methodologies	77
3. Basic Requirements	85
References	86
<b>Section 2</b>	<b>97</b>
<b>Introduction to Section 2: Methods and Outcomes for Infrequently Hand-Reared Species</b>	<b>99</b>
<b>6 The Effect of Hand Rearing on the Sexual and Maternal Competence of Three Species of Lemurs, <i>Varecia variegata</i>, <i>Varecia rubra</i>, and <i>Eulemur macaco</i></b>	<b>101</b>
<i>Kelli Niebruegge and Ingrid Porton</i>	
1. Introduction	101
2. Methods	103
3. Results	104
3.1. Reproductive Success: Parent-Reared and Hand-Reared Ruffed Lemurs	104
3.2. Maternal Competence: Parent-Reared and Hand-Reared Ruffed Lemurs	105

3.3. Reproductive Success: Peer versus Solitarily Hand-Reared Ruffed Lemurs	105
3.4. Maternal Competence: Peer versus Solitarily Hand-Reared Ruffed Lemurs	106
3.5. Reproductive Success: Hand-Reared and Parent-Reared Black Lemurs	106
3.6. Maternal Competence: Hand-Reared and Parent-Reared Black Lemurs	106
4. Discussion	107
References	109
<b>7 Nursery-Reared Prosimian Primates</b>	<b>111</b>
<i>M. Kay Izard</i>	
1. Introduction	111
2. Materials and Methods	113
3. Results	114
4. Discussion	116
References	117
<b>8 Hand Rearing of Infant Common Marmosets</b>	
<i>(Callithrix jacchus)</i>	121
<i>Bernhard Voelkl and Ludwig Huber</i>	
1. Introduction	121
2. Thermoregulation	121
3. Surrogates and Housing	122
4. Feeding	122
5. Feeding Schedule	124
6. Feeding Technique	125
7. Health	125
8. Weight Development	126
9. Reintroduction	126
References	127

<b>Section 3</b>	131
<b>Introduction to Section 3: Methods and Outcomes for Frequently Hand-Reared Species</b>	133
<b>9 Immunological Consequences of Nursery Rearing</b>	135
<i>Gabriele R. Lubach and Christopher L. Coe</i>	
1. Introduction	135
2. Development of the Infant Immune System	137
3. Immune Response of Nursery-Reared Infants	138
4. Immune Modulators in Breast Milk	146
5. Breast Milk and Gut Maturation	147
6. Th1/Th2	150
7. Temperature and Entrainment	151
8. Conclusions	154
9. Appendix	157
References	159
<b>10 Special Challenges of Rearing Infant Macaques Infected with Lentivirus (SIV, HIV, SHIV)</b>	169
<i>Julie M. Worlein, James C. Ha, Christy Harris, Jennifer Leigh, Kelsey Stratton, and Rodney J.R. Ho</i>	
1. Introduction	169
2. Lentiviruses and Viral Symptomology	170
3. Neuro-Aids Nursery Procedures	171
3.1. Personnel Safety	171
3.2. Rearing and Husbandry Protocols	173
4. Normative Data	179
4.1. Weights and Anthropometrics	179
4.2. Data Analysis	179
5. Cognitive Measures	181
5.1. Object Concept	181
5.2. Motor Development	182
5.3. Species-Typical Behaviors	184
6. Summary	185
References	186

<b>11</b>	<b>Nursery Rearing and Biobehavioral Organization</b>	<b>191</b>
	<i>John P. Capitanio, William A. Mason, Sally P. Mendoza, Laura DelRosso, and Jeffrey A. Roberts</i>	
1.	Introduction	191
2.	Biobehavioral Assessment of Infants at the California National Primate Research Center (CNPRC)	193
2.1.	Subjects and Living Conditions	193
2.2.	Assessment Procedures	195
2.3.	Results	198
3.	Discussion	206
4.	Implications	209
	References	213
<b>12</b>	<b>Neurobehavioral Assessment of Nonhuman Primate Neonates</b>	<b>215</b>
	<i>Mary L. Schneider, Maribeth Champoux, and Colleen F. Moore</i>	
1.	Introduction	215
2.	Description of the PNNA	218
3.	Studies at the University of Wisconsin	221
3.1.	Comparison of Nursery-Reared and Mother-Reared Infants	221
3.2.	Effects of Prenatal Stress on Early Neurobehavior	223
3.3.	Studies of Fetal Alcohol or Combined Alcohol and Prenatal Stress	229
4.	Studies at the Laboratory of Comparative Ethology	231
4.1.	General Differences from Studies at Wisconsin	231
4.2.	Genetic Influence on Behavioral Development	232
4.3.	Nutritional Influence on Development	235
5.	Summary and Future Directions	236
	References	238

<b>13</b>	<b>Is It Nutrients or Nurturing? Comparison of the Growth and Development of Mother-Reared and Laboratory-Reared Macaque Infants (<i>Macaca nemestrina</i>)</b>	<b>249</b>
	<i>Debra L. Durham and Laura L. Newell-Morris</i>	
1.	Introduction	249
2.	Materials and Methods	252
2.1.	Samples	252
2.2.	Data Collection	253
2.3.	Statistical Analysis	253
3.	Results	255
4.	Discussion	258
4.1.	Sex Effects	258
4.2.	Rearing Effects	260
5.	Conclusions, Limitations, and Suggestions for Future Research	262
	References	264
<b>14</b>	<b>Baboon Nursery Rearing Practices and Comparisons between Nursery-Reared and Mother-Reared Individuals</b>	<b>269</b>
	<i>Linda Brent and Anne Bode</i>	
1.	Introduction	269
2.	Nursery-Reared versus Mother-Reared Baboons	270
2.1.	Behavior	271
2.2.	Growth and Development	273
2.3.	Physiology	274
2.4.	Mortality and Morbidity	275
3.	Variation in the Nursery Environment	278
3.1.	Impact of Infant Formula Composition on Baboon Growth	279
3.2.	Impact of Human Handling on Behavior	279
3.3.	Impact of Socialization Program	280
4.	Changes in Nursery-Rearing Practices over Time	281
4.1.	Early Published Reports	282
4.2.	Changes over Time	283
4.3.	Learning from History	284

5. Conclusions	284
References	285
<b>15 Early Rearing Conditions and Captive Chimpanzee Behavior: Some Surprising Findings</b>	<b>289</b>
<i>Mollie A. Bloomsmith, Kate C. Baker, Stephen R. Ross, and Susan P. Lambeth</i>	
1. Introduction	289
2. Evolution of Nursery-Rearing Practices for Chimpanzees	291
3. Effects of Current Nursery Practices and Other Early Rearing Experiences on Behavioral Development of Chimpanzees	292
3.1. Abnormal Behavior	293
3.2. Response to Novelty	295
3.3. Sexual Competence	297
3.4. Maternal Competence	298
3.5. Maternal Response to Separation from Offspring	301
4. Conclusions	302
References	306
<b>16 Effects of Early Rearing History on Growth and Behavioral Development in Captive Chimpanzees (<i>Pan troglodytes</i>)</b>	<b>313</b>
<i>Susan M. Howell, Melanie Schwandt, Jo Fritz, Mary W. Marzke, James Murphy, and Dennis Young</i>	
1. Introduction	313
2. Methods	317
2.1. Housing and Husbandry	317
2.2. Data Collection and Analysis	321
3. Results	327
3.1. Growth	327
3.2. Positional Behavior	327
3.3. Solitary and Social Behavior	328
3.4. Behavior at Final Maternal Separation	331
4. Discussion	335
5. Appendix	338



5.1 Ethogram of Maternal Separation Behaviors	338
References	341
<b>Section 4</b>	<b>351</b>
<b>Introduction to Section 4: Nursery Care Methodology and Testing Techniques for the Future</b>	<b>353</b>
<b>17 Squirrel Monkeys as an Example of Primate Nursery Medicine</b>	<b>355</b>
<i>Alan G. Brady, Susan V. Gibson, Lawrence E. Williams, and Christian R. Abee</i>	
1. Introduction	355
2. Preventive Medicine Concepts for the Nursery	356
2.1. Nursery Design	356
2.2. Nursery Quality Control	357
2.3. Nursery Staffing	357
2.4. Nursery Hygiene, Disinfection, and Vermin Control	357
2.5. Nursery Records and Quality Control	359
3. The Squirrel Monkey Nursery	360
3.1. Admission	360
3.2. Feeding and Nutrition	361
3.3. Medical Procedures	362
3.4. Common Health Problems in Squirrel Monkey Infants	364
4. Conclusion	368
References	368
<b>18 Nursery Care of At-Risk Nonhuman Primates</b>	<b>371</b>
<i>Gerald C. Ruppenthal and Gene P. Sackett</i>	
1. Introduction	371
2. Critical Factors in Care of High-Risk Neonates	372
2.1. Hypothermia and Respiratory Abnormalities	373
3. Postincubator Housing	386
4. Causes of Death	386
5. Conclusion	389
References	389

<b>19</b>	<b>A Quick and Effective Method for Establishing Self-Feeding in Stump-Tailed Macaques</b>	
	<i>(Macaca arctoides)</i>	391
	<i>Arnold S. Chamove</i>	
	1. Introduction	391
	2. Nursery Facility	392
	3. Self-Feeding	393
	3.1. Effects of Preparation for Self-Feeding	394
	3.2. Comparative Outcomes of Feeding Methods	397
	4. Conclusion	399
	References	400
<b>20</b>	<b>Saliva as a Medium for Assessing Cortisol and Other Compounds in Nonhuman Primates: Collection, Assay, and Examples</b>	403
	<i>Mark L. Laudenslager, Tamara Bettinger, and Gene P. Sackett</i>	
	1. Background	404
	1.1. Free Cortisol in Saliva	406
	1.2. Other Compounds in Saliva	407
	2. Methods for Collecting Saliva from Nonhuman Primates	409
	3. Factors That Affect Salivary Hormones	411
	4. Application of Sampling Techniques and Interpretation of Results	414
	5. Summary and Conclusions	422
	References	423
<b>21</b>	<b>The SPIT Method for Simultaneous and Unobtrusive Collection of Salivary Cortisol from Individually Housed Infant Monkeys</b>	429
	<i>Peter G. Roma</i>	
	1. Introduction	429
	1.1. Ethics, Logistics, and Stress	430
	1.2. The Current State of the Art	432
	2. The SPIT Method	436
	2.1. The SPIT Apparatus	436

2.2. The SPIT Sticks	438
3. Application of the SPIT Method	441
3.1. Standard Operating Procedure	441
3.2. Viability of the SPIT Method	443
4. Discussion	452
4.1. Variations on a Theme	453
4.2. Limitations and Future Directions	454
5. Conclusion	455
References	456
<b>22 Actimetry Measurement of Behavioral Regulation and Sleep Cycles in Infant Rhesus Macaques (<i>Macaca mulatta</i>)</b>	<b>461</b>
<i>Peter J. Pierre, Allyson J. Bennett, and Stephen J. Suomi</i>	
1. Introduction	461
2. Materials and Methods	465
2.1. Subjects	465
2.2. Apparatus	466
2.3. Data Analysis	468
3. Results	471
3.1. Preliminary Assessment of Automated Recording Method	471
3.2. Comparison of SPR and PR Monkeys	472
4. Discussion	477
5. Summary	480
References	481
<b>23 Noninvasive Neuroimaging Techniques for the Study of Primate Brain Development</b>	<b>485</b>
<i>James K. Rilling</i>	
1. Introduction	485
2. Anatomical Imaging	486
2.1. Magnetic Resonance Imaging (MRI)	486
2.2. Diffusion Tensor Imaging (DTI)	492
2.3. Manganese Imaging	494
3. Functional Imaging	495

3.1. Positron Emission Tomography (PET)	495
3.2. Functional Magnetic Resonance Imaging (fMRI)	503
4. Conclusions	506
References	507
<b>24 Tethering with Maternal and Fetal Catheterization as a Model for Studying Pre- to Postnatal Continuities</b>	<b>513</b>
<i>Matthew Francis Stuart Xavier Novak</i>	
1. What Is Tethering?	513
2. Effects of Tethering	514
2.1. Maternal Effects	515
3. Maternal and Fetal Cardiovascular Functioning	523
3.1. Prenatal Stress and the Origins of Infant Reactivity and Sensitivity to the Environment	526
4. Tethering with Maternal and Fetal Catheterization for the Future	531
References	532
<b>Section 5</b>	<b>537</b>
<b>Introduction to Section 5: Hematology and Serum Chemistry Values</b>	<b>539</b>
<b>25 Hematology and Serum Chemistry in Young Captive Chimpanzees (<i>Pan troglodytes</i>)</b>	<b>541</b>
<i>Susan M. Howell, Kathleen Hoffman, Jo Fritz, and Melanie Schwandt</i>	
1. Introduction	541
2. Materials and Methods	543
2.1. Mother-Reared Chimpanzees	543
2.2. Nursery-Reared Chimpanzees	544
2.3. H/SCC Reference Intervals	545
2.4. H/SCC Analysis	547
3. Results	547
4. Discussion	547
References	575

<b>26</b>	<b>Hematology and Serum Chemistry Reference Values for Rhesus Macaque (<i>Macaca mulatta</i>) Infants</b>	<b>577</b>
	<i>John P. Capitanio</i>	
<b>27</b>	<b>Hematology and Serum Chemistry Reference Values for Pigtailed Macaque (<i>Macaca nemestrina</i>) Infants</b>	<b>583</b>
	<i>Erika Rainwater</i>	
<b>28</b>	<b>Hematology and Serum Chemistry Reference Values for Mother-Reared Squirrel Monkey (<i>Saimiri boliviensis boliviensis</i>) Infants</b>	<b>593</b>
	<i>Lawrence E. Williams</i>	
	<b>Index</b>	<b>597</b>

## CONTRIBUTORS

**Christian R. Abee**, Department of Comparative Medicine, University of South Alabama, Mobile, AL 36688, USA

**Kate C. Baker**, Tulane National Primate Research Center, Veterinary Medicine, Covington, LA 70433, USA

**Allyson J. Bennett**, Physiology/Pharmacology and Pediatrics, Wake Forest University School of Medicine, Winston-Salem, NC 27157, USA

**Tamara Bettinger**, Cleveland Metroparks Zoo, Conservation and Science, Cleveland, OH 44109, USA

**Mollie A. Bloomsmith**, Zoo Atlanta, Research/TECH Lab, Atlanta, GA 30315

**Ann Bode**, Southwest Foundation for Biomedical Research San Antonio, TX 78245, USA

**Alan G. Brady**, Department of Comparative Medicine, University of South Alabama Mobile, AL 36688, USA

**Linda Brent**, President and Director, Chimp Haven, Inc., Leithville, LA 71047, USA

**John P. Capitanio**, California National Primate Research Center, University of California, Davis, CA 95616, USA

**Arnold S. Chamove**, Massey University School of Psychology, Palmerston North, 5331 New Zealand

**Maribeth Champoux**, Laboratory of Comparative Ethology, National Institutes Animal Center, NIH, National Institute of Child Health and Human Development, Poolesville, MD 20837, USA

**Christopher L. Coe**, Harlow Primate Laboratory, University of Wisconsin, Madison, WI 53715-1239, USA

**Carolyn M. Crockett**, Washington National Primate Research Center, University of Washington, Seattle, WA 98195, USA

**Arthur E. Davis**, Washington National Primate Research Center, University of Washington, Seattle, WA 98195, USA

**Laura DelRosso**, California National Primate Research Center, University of California, Davis, CA 95616, USA

**Debra L. Durham**, Young Hall Department of Anthropology, University of California Animal Behavior Graduate Group, Davis, CA 95616, USA

**Jo Fritz**, Primate Foundation of Arizona, Mesa, AZ 85277, USA

**Susan V. Gibson**, Department of Comparative Medicine, University of South Alabama, Mobile, AL 36688, USA

**James C. Ha**, Washington National Primate Research Center, University of Washington, Seattle, WA 98195, USA

**Christy Harris**, Washington National Primate Research Center, University of Washington, Seattle, WA 98195, USA

**Rodney J. R. Ho**, Department of Pharmaceutics, University of Washington, Seattle, WA 98195, USA

**Kathleen Hoffman**, Primate Foundation of Arizona, Mesa, AZ 85277, USA

**Susan M. Howell**, Alpha Genesis Research, Yemassee, SC 29945, USA

**Ludwig Huber**, Institute of Zoology, University of Vienna, Vienna A-1090, Austria

**M. Kay Izard**, Alamogordo Primate Facility, Holloman AFB, NM 88330, USA

**Susan P. Lambeth**, Department of Veterinary Sciences, University of Texas, M. D. Anderson Cancer Center, Bastrop, TX 78602, USA

**Mark L. Laudenslager**, Department of Psychiatry, University of Colorado Health Sciences Center, Denver, CO 80220, USA

**Jennifer Leigh**, Washington National Primate Research Center, University of Washington, Seattle, WA 98195, USA

- Gabriele R. Lubach**, Harlow Primate Laboratory, University of Wisconsin, Madison, WI 53715, USA
- Mary W. Marzke**, Department of Anthropology, Arizona State University, Tempe, AZ 85287, USA
- William A. Mason**, California National Primate Research Center, University of California, Davis, CA 95616, USA
- Sally P. Mendoza**, California National Primate Research Center, University of California, Davis, CA 95616, USA
- Colleen F. Moore**, Department of Psychology, Harlow Primate Laboratory, University of Wisconsin, Madison, WI 53715, USA
- James Murphy**, Primate Foundation of Arizona, Mesa, AZ 85277, USA
- Laura L. Newell-Morris**, Department of Anthropology, University of Washington, Seattle, WA 98195, USA
- Kelli Niebruegge**, Saint Louis Zoo, St. Louis, MO 63110, USA
- Matthew Francis Stuart Xavier Novak**, Laboratory of Comparative Ethology, National Institutes Animal Center, NIH, National Institute of Child Health and Human Development, Poolesville, MD 20837, USA
- Melinda A. Novak**, Department of Psychology, University of Massachusetts, Amherst, MA 01003, USA
- Peter J. Pierre**, Physiology/Pharmacology and Pediatrics, Wake Forest University School of Medicine, Winston-Salem, NC 27157, USA
- Ingrid Porton**, Saint Louis Zoo, St. Louis, MO 63110, USA
- Erika Rainwater**, Washington National Primate Research Center, University of Washington, Seattle, WA 98195, USA
- James K. Rilling**, Department of Anthropology, Emory University, Atlanta, GA 30322, USA
- Jeffrey A. Roberts**, California National Primate Research Center, University of California, Davis, CA 95616, USA
- Peter G. Roma**, NIH Animal Center, Poolesville, MD 20837, USA
- Stephen R. Ross**, Lincoln Park Zoo, Conservation and Science, Chicago, IL 60614, USA



**Gerald C. Ruppenthal**, Washington National Primate Research Center,  
University of Washington, Seattle, WA 98195, USA

**Gene P. Sackett**, Washington National Primate Research Center,  
University of Washington, Seattle, WA 98195, USA

**Mary L. Schneider**, Departments of Kinesiology and Psychology,  
Harlow Primate Laboratory, University of Wisconsin, Madison, WI  
53715, USA

**Melanie Schwandt**, National Institutes Animal Center, NIH/NIAAA,  
Poolesville, MD 20837, USA

**Kelsey Stratton**, Washington National Primate Research Center,  
University of Washington, Seattle, WA 98195, USA

**Stephen J. Suomi**, Laboratory of Comparative Ethology, National Insti-  
tute of Child Health and Human Development, Bethesda, MD 20892,  
USA

**Bernhard Voelkl**, Institute of Zoology, University of Vienna, Vienna  
A-1090, Austria

**Lawrence E. Williams**, Department of Comparative Medicine,  
University of South Alabama, Mobile, AL 36688-0002, USA

**Julie M. Worlein**, Washington National Primate Research Center,  
University of Washington, Seattle, WA 98195, USA

**Dennis Young**, Department of Anthropology, Arizona State University,  
Tempe, AZ 85287, USA

# INTRODUCTION

As described in the preface, this book originated in a workshop focused on changes in nursery-rearing practices over the past 35 years and the state of the art in the early 21st century. In designing the workshop, we identified four areas of change: (1) new or modified goals of nursery rearing, (2) new concepts concerning these goals, (3) new methods for attaining these goals, and (4) new data concerning the effects of nursery or hand rearing on the health and biobehavioral and social development of infant and juvenile primates.

## 1. GOALS

There are two primary goals of contemporary nursery rearing. The first involves saving at-risk newborns and young infants that cannot be reared by their mothers. This goal serves the purposes of conservation of endangered species, display in zoos, production of future breeders, and preservation of natural models of human health or behavior problems. Examples of the latter include low-birth-weight or premature neonates and neonates with genetic defects such as trisomic chromosome conditions. The second goal involves nursery rearing and its variations as specific experimental procedures in research studies. Examples of new research goals include the need for biological containment of neonates and infants in viral and other disease research, the production of specific pathogen-free (SPF) colonies by removal of neonates from the mother, and the production of phenotypes for genome manipulation, assisted reproduction technology, and molecular biology studies.

## 2. CONCEPTS

A major change in concepts concerning nursery rearing is that nursery-reared primates no longer are simply warehoused for future assignment to research projects. Instead, modern methods are aimed at providing psychologically rich environments to foster reasonably normative behavioral and physiological development as compared with some standard such as rearing with mothers in captive environments. The underlying concept is that normal animals make better research subjects. In the extreme view, only normal animals provide valid subjects in most primate research projects, whether these are behavioral or biological in nature. A variant of this view is that some degree of normal development is necessary for producing successful breeders and healthy colony members. A major problem, however, is how to define “normal.” Many of the chapters in this book are relevant to this definitional issue.

On the other hand, research over the past 50 years in developmental sciences, ranging from molecular biology to developmental psychology, shows that genes and environment work together to produce a variety of “normal” phenotypes at all levels of study (e.g., Gottlieb, 1998). With respect to the development of nonhuman primates following variations in rearing conditions, gene–environment interactions appear to be the norm rather than the exception. An important example of this interaction in nonhuman primates is seen in work by Suomi and his colleagues at the Laboratory of Comparative Ethology of the National Institute of Child Health and Human Development.

Rhesus macaques have a variation in the serotonin transporter gene regulatory region (5-HTTLPR), with some individuals having a long allele and some having a short allele. Humans have a similar polymorphism in this same region, which appears to be associated with phenotypic variation in levels of anxiety, depression, affective disorders, and aggression. In one study, Bennet *et al.* (2002) compared concentrations of serotonin in the cerebrospinal fluid of monkeys that were reared with their mothers versus monkeys that were reared in a nursery and then housed with agemates. Among nursery-peer monkeys, those with the short allele had a marked reduction in serotonin compared with monkeys that had the long allele. Similarly, in a study of social play and aggres-

sion (Barr *et al.*, 2003), nursery-peer monkeys with the long allele displayed more play and less aggression than those with the short allele, whereas mother-reared infants showed no allele-related differences in behavior. Thus, the effects of genotype on both neurochemistry and behavior depended on how the monkeys were reared.

We were not surprised by these results. In two studies we addressed the question of species differences in the effects of social-isolation rearing (Sackett *et al.*, 1976, 1981). Three species of macaque—rhesus (*Macaca mulatta*), pigtailed (*M. nemestrina*), and longtailed (*M. fascicularis*)—were reared in identical environments with no social or sensory contact with other monkeys for 6–7 months from birth. During the rearing period the rhesus macaques developed a typical isolation syndrome: they displayed no play or exploration behaviors and spent most of their time in self-directed and repetitive behaviors. Longtailed macaques displayed more moderate levels of the isolation syndrome, while pigtailed macaques showed much lower levels of isolate behavior and a relatively high level of play. During postrearing social behavior tests, rhesus macaques continued to show mostly isolate syndrome behaviors, with no play or socially initiated activity. Pigtailed macaques had greatly reduced isolate syndrome behavior, and engaged in some positive social behavior and the same high levels of environmental exploration as controls reared with mothers and peer experience. Longtailed macaques also had a great deal of isolate behavior, but engaged in as much positive social behavior as did control animals reared with mothers and peers. Thus, when reared in an identical impoverished environment, genetically different primate species were differentially affected in degree of both deviant and species-typical behaviors. Furthermore, the results showed that the classic “isolation rearing syndrome” of abnormal personal behavior, neophobia, and lack of social behavior was valid only for the rhesus macaque species.

The lesson of studies such as these is that we should expect to see variations in the effects of nursery rearing both within and between species. This variation does not necessarily mean that we have produced abnormal monkeys. Rather, depending on genotype, each species and individual responds to environmental variation with behaviors that are adaptive in that environment. Motherless rearing in a nursery imposes a major

challenge on this adaptability during and after the rearing experience. Chapters in this book suggest that some primate species, especially prosimians, may be difficult to rear under motherless conditions, whereas other species appear to thrive when reared under modern husbandry and social conditions (e.g., Sackett *et al.*, 2002). We believe that there are nursery-rearing conditions that can produce adaptable juveniles and adults, capable of reproducing their species, for all normal genotypes of all primate species. Although this ideal has not been accomplished for all species to date, we hope the data presented in this book and the questions these data raise for future research will help us learn how to attain this goal.

### 3. METHODS

Research over the past 35 years has led to the development of new nursery-rearing methods. So far, these methods have been specific for particular primate species and institutions that rear primates in captivity. In addition, the psychological well-being movement and the Institutional Animal Care Committee (IACC) have introduced new dimensions into the methods for rearing primates in captivity. These dimensions involve both the physical environment and social-behavioral considerations. In this context, rules and regulations regarding rearing methods may bring bureaucracy into conflict with the conditions that actually foster development for meeting the goals of research, breeding and husbandry, conservation, or public display. IACC and related regulations specify factors ranging from cage sizes to protective gear for primate researchers and caregivers. This has greatly increased the costs of nursery rearing and of doing research with nonhuman primates in general. It has also greatly reduced both the quantity and quality of contact between humans and their monkey charges. On the other hand, these influences have greatly increased the quality and quantity of peer social contact and nonsocial environmental enrichment afforded nursery-reared individuals. A number of methods to cope with these influences are illustrated in chapters in this book, but many issues still remain to be solved by future research and technological innovation.

#### 4. DATA

Newer data of particular importance concern variations in physiological and growth systems that differentially affect nursery-reared compared with mother-reared primates. Examples of such data are maturational, immunological, neurochemical, and hormonal effects that impact all aspects of development. Such information is critical for identifying appropriate research subjects in biobehavioral experiments, as well as for understanding deviations from normative developmental patterns. These new data are also of importance for understanding nongenetic intergenerational phenomena that affect the health and behavior of future offspring. Of course, new data identifying conditions that produce healthy and adaptive nursery-reared individuals are equally important. Chapters throughout the first four sections of this book present such data.

#### 5. CHAPTER ORGANIZATION

The chapters in this book represent as wide a range of genera—great apes, macaques and baboons, squirrel and marmoset monkeys, and prosimians—as we could identify for which developmental data on nursery-reared animals have been collected systematically under describable conditions. The book is organized in five sections. Section 1 presents a brief history of nursery rearing and some practical and theoretical issues bearing on contemporary nursery-rearing practices. Sections 2 and 3 present methods and outcomes of nursery rearing in prosimian and simian species. Section 4 deals with general veterinary issues, the rearing of high-risk infants, and some contemporary rearing and research methods important for current and future studies of primate development. The fifth section presents some difficult-to-find health data for representative species commonly reared in nursery environments.

*Gene P. Sackett*  
*Gerald C. Ruppenthal*  
*Kate Elias*