Biology and Diseases of the Ferret

Third Edition
Biology and Diseases of the Ferret

Third Edition

Edited by

James G. Fox
Robert P. Marini

WILEY Blackwell
This book is dedicated to my wife, Jody, and my children, Anne and Jim. Their love, continued support, and patience provided sustenance and good cheer throughout, making the effort worthwhile, and most of the time, enjoyable.

—JGF

To my dear ones, Debbie, Thalia, and Ianthe, for their love and support.

—RPM
## Contents

*Contributors*  
*Preface*  

### Section I  Biology and Husbandry

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Authors/Contributors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Taxonomy, History, and Use</td>
<td>James G. Fox</td>
</tr>
<tr>
<td>2</td>
<td>Anatomy of the Ferret</td>
<td>Howard Evans and Nguyen Quoc An</td>
</tr>
<tr>
<td>3</td>
<td>Neuroanatomy of the Ferret Brain with Focus on the Cerebral Cortex</td>
<td>Christopher D. Kroenke, Brian D. Mills, Jaime F. Olavarria, and Jeffrey J. Neil</td>
</tr>
<tr>
<td>4</td>
<td>Physiology of the Ferret</td>
<td>Mark T. Whary</td>
</tr>
<tr>
<td>5</td>
<td>Nutrition of the Ferret</td>
<td>James G. Fox, Carrie S. Schultz, and Brittany M. Vester Boler</td>
</tr>
<tr>
<td>6</td>
<td>Housing and Management</td>
<td>James G. Fox and Rosemary Broome</td>
</tr>
<tr>
<td>7</td>
<td>Normal Clinical and Biological Parameters</td>
<td>James G. Fox</td>
</tr>
<tr>
<td>8</td>
<td>Growth and Reproduction</td>
<td>James G. Fox, Judith A. Bell, and Rosemary Broome</td>
</tr>
<tr>
<td>9</td>
<td>Regulatory Considerations</td>
<td>Robert P. Marini</td>
</tr>
<tr>
<td>10</td>
<td>Recovery of the Black-Footed Ferret</td>
<td>Rachel Santymire, Heather Branvold-Faber, and Paul E. Marinari</td>
</tr>
</tbody>
</table>

### Section II  Diseases and Clinical Applications

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Authors/Contributors</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Physical Examination, Preventive Medicine, and Diagnosis in the Ferret</td>
<td>Robert P. Marini</td>
</tr>
<tr>
<td>12</td>
<td>Anesthesia</td>
<td>Jeff C. Ko and Robert P. Marini</td>
</tr>
<tr>
<td>13</td>
<td>Surgery</td>
<td>Stephen J. Mehler</td>
</tr>
<tr>
<td>14</td>
<td>Diseases of the Hematopoietic System</td>
<td>Jörg Mayer, Susan E. Erdman, and James G. Fox</td>
</tr>
<tr>
<td>Chapter</td>
<td>Title</td>
<td>Authors</td>
</tr>
<tr>
<td>---------</td>
<td>------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>15</td>
<td>Diseases of the Genitourinary System</td>
<td>James G. Fox and Judith A. Bell</td>
</tr>
<tr>
<td>16</td>
<td>Diseases of the Gastrointestinal System</td>
<td>Kirk J. Maurer and James G. Fox</td>
</tr>
<tr>
<td>17</td>
<td>Diseases of the Endocrine System</td>
<td>Cassandra L. Miller, Robert P. Marini, and James G. Fox</td>
</tr>
<tr>
<td>18</td>
<td>Diseases of the Cardiovascular System</td>
<td>Robert A. Wagner</td>
</tr>
<tr>
<td>19</td>
<td>Other Systemic Diseases</td>
<td>James G. Fox</td>
</tr>
<tr>
<td>20</td>
<td>Viral Diseases of Ferrets</td>
<td>Matti Kiupel and David Perpiñán</td>
</tr>
<tr>
<td>21</td>
<td>Bacterial and Mycoplasmal Diseases</td>
<td>Alton G. Swennes and James G. Fox</td>
</tr>
<tr>
<td>22</td>
<td>Parasitic Diseases</td>
<td>Mary M. Patterson, James G. Fox, and Mark L. Eberhard</td>
</tr>
<tr>
<td>23</td>
<td>Mycotic Diseases</td>
<td>James G. Fox</td>
</tr>
<tr>
<td>24</td>
<td>Neoplastic Diseases</td>
<td>James G. Fox, Sureshkumar Muthupalani, Matti Kiupel, and Bruce Williams</td>
</tr>
<tr>
<td>25</td>
<td>The Ferret in Viral Respiratory Disease Research</td>
<td>Deborah R. Taylor</td>
</tr>
<tr>
<td>26</td>
<td>The Ferret in Morbillivirus Research</td>
<td>Veronika von Messling</td>
</tr>
<tr>
<td>27</td>
<td>Use of the Ferret in Cardiovascular Research</td>
<td>James P. Morgan</td>
</tr>
<tr>
<td>28</td>
<td>Genetic Engineering in the Ferret</td>
<td>Xingshen Sun, Zijing Yan, Xiaoming Liu, Alicia K. Olivier, and John F. Engelhardt</td>
</tr>
<tr>
<td>29</td>
<td>Hearing and Auditory Function in Ferrets</td>
<td>Fernando R. Nodal and Andrew J. King</td>
</tr>
<tr>
<td>30</td>
<td>The Ferret as a Model for Visual System Development and Plasticity</td>
<td>Jitendra Sharma and Mriganka Sur</td>
</tr>
<tr>
<td>31</td>
<td>The Ferret in Nausea and Vomiting Research: Lessons in Translation of Basic Science to the Clinic</td>
<td>Nathalie Percie du Sert and Paul L.R. Andrews</td>
</tr>
<tr>
<td>32</td>
<td>The Ferret in Lung Carcinogenesis and Nutritional Chemoprevention Research</td>
<td>Xiang-Dong Wang and Chun Liu</td>
</tr>
</tbody>
</table>

Index  
795
Contributors

Nguyen Quoc An, DVM, MS
College of Veterinary Medicine
University of Georgia
Athens, GA

Paul L.R. Andrews, PhD
Emeritus Professor of Comparative Physiology
Division of Biomedical Sciences
St George’s University of London
London, UK

Judith A. Bell, DVM, PhD
Ontario Veterinary College
University of Guelph
Guelph, Ontario, Canada

Heather Branvold-Faber, MS, DVM
Wellington, CO

Rosemary Broome, DVM, MPVM
Associate Director
MedImmune LLC
Mountain View, CA

Mark L. Eberhard, PhD
Director
CGH Division of Parasitic Diseases and Malaria
Centers for Disease Control and Prevention
Atlanta, GA

John F. Engelhardt, PhD
Professor
Department of Anatomy and Cell Biology
College of Medicine
University of Iowa
Iowa City, IA

Susan E. Erdman, DVM, MPH, DACLAM
Assistant Director and Principal Research Scientist
Division of Comparative Medicine
Massachusetts Institute of Technology
Cambridge, MA

Howard Evans, PhD
Professor Emeritus of Veterinary and Comparative Anatomy
Veterinary College
Cornell University
Ithaca, NY

James G. Fox, DVM, MS, DACLAM
Professor and Director
Division of Comparative Medicine
Massachusetts Institute of Technology
Cambridge, MA

Andrew J. King, PhD
Professor of Neurophysiology
Department of Physiology
Anatomy and Genetics
University of Oxford
Oxford, UK

Matti Kiupel, MVSc, PhD
Associate Professor
Department of Pathobiology and Diagnostic Investigation
Michigan State University
Lansing, MI

Jeff C. Ko, DVM, MS, DACV A
Professor
Department of Anesthesiology
Purdue University College of Veterinary Medicine
West Lafayette, IN
Contributors

Christopher D. Kroenke, PhD
Advanced Imaging Research Center
Oregon National Primate Research Center
Oregon Health and Science University
Portland, OR

Chun Liu, MD, MS/MPH
Jean Mayer USDA Human Nutrition Research Center on Aging
Tufts University
Boston, MA

Xiaoming Liu, PhD
Department of Anatomy and Cell Biology
University of Iowa
Iowa City, IA

Paul E. Marinari, MS
Senior Curator
Center for Species Survival
Smithsonian Conservation Biology Institute
National Zoological Park
Front Royal, VA

Robert P. Marini, DVM, DACLAM
Assistant Director, Chief
Veterinary Surgical Resources
Division of Comparative Medicine
Massachusetts Institute of Technology
Cambridge, MA

Kirk J. Maurer, DVM, PhD, DACLAM
Associate Director and Attending Veterinarian
Center for Comparative Medicine and Research
Dartmouth College
Lebanon, NH

Jörg Mayer, DVM, MS
President of the Association of Exotic Mammal Veterinarians
Associate Professor of Zoological Medicine
College of Veterinary Medicine
University of Georgia
Atlanta, GA

Stephen J. Mehler, DVM, Diplomate ACVS
Hope Veterinary Specialists
Malvern, PA

Cassandra L. Miller, DVM
Division of Comparative Medicine
Massachusetts Institute of Technology
Cambridge, MA

Brian D. Mills, MS (PhD student in Behavioral Neuroscience)
Oregon Health and Science University
Portland, OR

James P. Morgan, PhD
Professor of Medicine
Tufts University School of Medicine
Service Chief
Cardiology
Steward Carney Hospital
Dorchester, MA

Sureshkumar Muthupalani, BVSc, PhD, DACVP
Comparative Pathologist
Division of Comparative Medicine
Massachusetts Institute of Technology
Cambridge, MA

Jeffrey J. Neil, MD, PhD
Professor of Neurology, Pediatrics, Radiology, and Anatomy and Neurobiology
Department of Neurology
Washington University School of Medicine
St. Louis, MO

Fernando R. Nodal, PhD
Department of Physiology
Anatomy and Genetics
University of Oxford
Oxford, UK

Jaime F. Olavarria, MD, PhD
Associate Professor
Department of Psychology
University of Washington
Seattle, WA
Alicia K. Olivier, DVM, PhD, DACVP
Department of Pathology
University of Iowa
Iowa City, IA

Mary M. Patterson, MS, DVM, DACLAM
Clinical Veterinarian, Chief of Primate Resources
Division of Comparative Medicine
Massachusetts Institute of Technology
Cambridge, MA

Nathalie Percie du Sert, PhD
Programme Manager
National Centre for the Replacement, Refinement and Reduction of Animals in Research
London, UK

David Perpiñán, LV, MSc, Dip ECZM (Herpetology)
Zoological Veterinary Specialist
Hospital for Small Animals
Royal (Dick) School of Veterinary Studies
The University of Edinburgh
Midlothian, UK

Rachel Santymire, MS, PhD
Director
Davee Center for Epidemiology and Endocrinology
Lincoln Park Zoo
Chicago, IL

Carrie S. Schultz, PhD
Nutritionist
Land O’Lakes Purina Feed LLC
St. Louis, MO

Jitendra Sharma, PhD
Research Scientist
Picower Institute for Learning and Memory
Massachusetts Institute of Technology

Xingshen Sun, PhD
Associate Research Scientist/Engineer
Department of Anatomy and Cell Biology
University of Iowa
Iowa City, IA

Mriganka Sur, PhD
Paul E. and Lilah Newton Professor of Neuroscience
Picower Institute for Learning and Memory
Director
Simons Center for the Social Brain
Department of Brain and Cognitive Sciences
Massachusetts Institute of Technology
Cambridge, MA

Alton G. Swennes, MS, DVM
Clinical Veterinarian
Center for Comparative Medicine
Baylor College of Medicine
Houston, TX

Deborah R. Taylor, PhD
Laboratory of Emerging Pathogens
Division of Emerging and Transfusion-Transmitted Diseases
Office of Blood Research and Review
CBER FDA
Bethesda, MD

Brittany M. Vester Boler, MS, PhD
Nutritionist
Land O’Lakes Purina Feed LLC
St. Louis, MO

Veronika von Messling, Dr. Med. Vet.
Director
Division of Veterinary Medicine
Paul-Erlich Institute
Federal Institute for Vaccines and Biomedicines
Langen, Germany

Robert A. Wagner, VMD, Diplomat ACVP-ECM
Division of Laboratory Animal Resources
University of Pittsburgh
Pittsburgh, PA
Contributors

Xiang-Dong Wang, MD, PhD
Director and Senior Scientist
Nutrition and Cancer Biology Laboratory
Jean Mayer USDA Human Nutrition Research Center on Aging
Tufts University
Boston, MA

Mark T. Whary, DVM, PhD, DACLAM
Associate Director
Division of Comparative Medicine
Massachusetts Institute of Technology
Cambridge, MA

Bruce Williams, DVM, DACVP
Senior Pathologist
Veterinary Pathology Service
Joint Pathology Center
Rockville, MD

Ziying Yan, PhD
Department of Anatomy and Cell Biology
University of Iowa
Iowa City, IA

CONTENT REVIEWERS

Roberta Scipioni Ball, DVM, MS, DACLAM
Marshall BioResources
North Rose, NY

Dean E. Biggins, PhD
Research Wildlife Biologist
U.S. Geological Survey (BRD)
Fort Collins Science Center
Fort Collins, CO

Catherine M. Brown, DVM, MSc, MPH
State Public Health Veterinarian
Massachusetts Department of Public Health
Hinton State Laboratory Institute
Jamaica Plain, MA

Edward J. Dubovi, PhD
Professor and Director
Virology Laboratory
Animal Health Diagnostic Center
College of Veterinary Medicine
Cornell University
Ithaca, NY

Mark Eberhard, PhD
Director of CGH Division of Parasitic Diseases and Malaria
Centers for Disease Control
Atlanta, GA

Walter E. Finkbeiner, MD, PhD
Professor, Vice Chair and Chief of Pathology
Department of Pathology
UCSF
San Francisco General Hospital
San Francisco, CA

Vincent Girod, PhD
Head of In Vivo Pharmacology
Syncrosome
Marseille, France

Lisa Karr-Lillenthal, PhD
Assistant Professor
Animal Science Department
University of Nebraska
Lincoln, NE

Angela M. Lennox, DVM, DABVP
Owner
Avian and Exotic Animal Clinic of Indianapolis
Indianapolis IN

Xiantang Li, DVM, PhD
Pathologist
Pfizer
Groton, CT

Marla Lichtenberger, DVM, DACVECC
Milwaukee Emergency Center for Animals
Milwaukee, WI

Jörg Mayer, DVM, MS, DABVP, DECZM
Associate Professor of Zoological Medicine
College of Veterinary Medicine
University of Georgia
Athens, GA

Michael Oglesbee, DVM, PhD, DACVP
Professor and Chair
Department of Veterinary Biosciences
The Ohio State University
Columbus, OH
Connie Orcutt, DVM, DABVP
Avian and Exotic Animal Medicine
Putnam Veterinary Clinic
Topsfield, MA

Andreu Palou, PhD
Director of the General Laboratory of Molecular Biology
Nutrition and Biotechnology
Universitat de les Illes Balears
Palma de Mallorca, Spain

Christal Pollock, DVM
Veterinary Consultant
Lafeber Company
Cornell, IL

Keith Sharkey, PhD
Hotchkiss Brain Institute
University of Calgary
Calgary, Canada

David Wildt, PhD
Head
Center for Species Survival
Smithsonian Conservation Biology Institute
Front Royal, VA

Jeffrey J. Wine, PhD
Professor and Director of the Cystic Fibrosis Research Laboratory
Stanford University
Stanford, CA

Ryan M. Yamka, PhD, MS, MBA, PAS, DACAS
Senior Director
Research and Development–Nutrition/Wellness
The Hartz Mountain Corporation
Bloomfield, NJ
Preface

To whom shall I offer this fresh little book, just smoothed off with dry pumice-stone?

The Dedication: to Cornelius

—Catullus

The creation of the third edition of this text, conceived, compiled, and written 14 years after its predecessor, and 25 years after the first edition was printed, was motivated by the burgeoning clinical and scientific literature concerning the ferret. As a research animal, the ferret has contributed greatly to a number of disciplines, but most particularly to neuroscience, influenza, and other infectious diseases. As a pet, it has inspired a fervent ownership, and is attended by a growing number of expert and passionate clinicians. Pet owners, veterinarians, and researchers delight at this playful and animated creature. Moreover, the peculiar propensity of ferrets toward development of endocrine disorders and its unique susceptibility to human influenza virus, as well as to emerging diseases, such as the FIP-like ferret systemic coronavirus and disseminated idiopathic myofasciitis, have fascinated both veterinary clinicians and scientists.

Our own interest in the species emerged on both clinical and research fronts. During investigations into factors influencing gastric carcinogenesis, one of our postdoctoral fellows submitted biopsies of a gastric ulcer from an experimental ferret to our diagnostic laboratory, an action which led to the discovery and eventual characterization of Helicobacter mustelae. This organism and its disease expression in the ferret remains a robust model for Helicobacter pylori of humans. At the same time, practitioners solicited help in understanding and treating conditions in ferrets, which were gaining in popularity as pets. In the course of providing such assistance, and as we adapted methodologies for the diagnosis and treatment of both privately owned ferrets and those in our institutional colonies, our sustained and enthusiastic appreciation for these engaging animals was born.

The third edition has been expanded to 32 chapters, with new chapters devoted to black-footed ferret recovery, regulatory considerations, cardiovascular disease, genetic engineering, auditory neuroscience, vision and visual plasticity, emesis, and nutritional chemoprevention of cancer. These new chapters reflect current usage and advances. At the same time, some of the traditional research uses of ferrets have diminished in importance and these have either been eliminated or merged into clinical chapters when appropriate. The contributions of those second edition authors whose chapters are no longer included are acknowledged in these respective chapters. All chapters have been revised to accommodate new findings. The second edition chapter entitled “Anesthesia, Surgery, and Biomethodology” has been replaced by three separate chapters whose subject matter bears either the same name, or, in the case of “Biomethodology,” the new designation, “Physical Examination, Preventative Medicine, and Diagnosis.” The third edition also features many color photographs and is accompanied by an electronic version. We gratefully acknowledge the support and gentle persistence of our partners at Wiley, particularly their liaison and managing editor, Susan Engelken. Additionally, this text is now published under the auspices of the American College of Laboratory Animal Medicine (ACLAM). We are indebted to our assistants, principally Lucy Wilhelm and Alyssa Terestre, and also to Elaine Robbins for their skill and endurance and for overlooking our occasional excesses. Theirs was a Herculean effort, and they bore it all with patience and equanimity. Finally, we thank our families for their love and support, and for forgiving our absences, delayed arrivals, and missed appointments. Without the solace of their company, the joy and light of every day would be much diminished.

We would like to recognize those colleagues, particularly the veterinary staff in the MIT Division of Comparative Medicine, as well as postdoctoral fellows and technicians, who helped advance the care and our understanding of the biology and naturally occurring diseases of these animals during the early years. We also acknowledge and thank the many authors who have contributed their expertise by generously providing
chapters in both past and present editions. Their scholarship forms the foundation of current medical practice, surgical intervention, and animal model development. At the same time, we look forward to and anticipate the efforts of those clinicians, researchers, and students who will use this current edition to aid in the discovery of the next generation of research and clinical findings that will advance our knowledge of this fascinating animal.

James G. Fox
Robert P. Marini
Biology and Husbandry
Taxonomy, History, and Use

James G. Fox

TAXONOMY

Ferrets (Mustela putorius furo), like the stoat, weasel, badger, skunk, otter, and mink, are carnivores, and belong to the ancient family Mustelidae, which probably dates back to the Eocene period, some 40 million years ago (Fig. 1.1). The taxonomic groups in the family Mustelidae, as recognized by Corbet and Hill, include 67 species from North, Central, and South America, Eurasia, and Africa (Table 1.1) [1]. No other carnivore shows such diversity of adaptation, being found in a wide variety of ecosystems, ranging from arctic tundra to tropical rain forests. Mustelids have retained many primitive characteristics which include relatively small size, short, stocky legs, five toes per foot, elongated brain case, and short rostrum [2]. The genus Mustela is divided into five subgenera: Mustela (weasels), Lutreola (European mink), Vison (American mink), Putorius (ferrets), and Grammogale (South American weasels). The Mustelinae are the central subfamily of the Mustelidae. The best-known members of the Mustelinae are the weasels, mink, and ferrets (genus Mustela) and the martens (genus Martes) [2].

ORIGIN

The domestic ferret is often confused with the North American black-footed ferret, Mustela nigripes, which shows a striking physical similarity to Mustela eversmannii (the steppe polecat), so a short description of each will be provided to clarify the differences.

Domestic Ferret

According to one author, ferrets (M. putorius furo) have been domesticated for over 2000 years [3], but confusion exists because of the scarcity of written records, the use of different nomenclature in different regions, and translation difficulties from one language to another. Aristotle, in his early descriptions (ca. 350 BC), stated that there existed an animal, which may have been a ferret, that could become very mild and tame [3].

Early accounts in Greek and Roman literature from Strabo (ca. 63 BC–AD 24) and Pliny (AD 23–79) noted that ferrets were used for hunting rabbits. These earlier references to ferrets are probably the basis of the belief that ferrets originated in North Africa (Fig. 1.2) [3]. This belief has been questioned and a premise put forth that ferrets were first domesticated in countries of Southern Europe, bordering the Mediterranean [4]. Evidently, ferrets were bred specifically for rabbeting (rabbit hunting) and were muzzled before being sent into rabbit burrows. This practice was later introduced into Asia, and the British Isles, where the sport is still practiced today. The first illustration of ferrets used for rabbeting occurs in a fourteenth-century manuscript (Fig. 1.3) [3].

In the Linnaean classification system, the ferret was named Mustela furo, and its identity has remained firmly established since then. The word “ferret” is derived from the Latin furonem and the Italian furone, meaning thief [3,5]. The word “putorius” is derived from the Latin putor,
a stench, which applies to the musky odor of the ferret. Today, “ferret” is also used as a verb and connotes the ferret’s behavior and traits: to remove from a hiding place, to search out with keenness, or to draw out by shrewd questioning.

The ferret (*M. putorius furo*) has been and is now used for hunting, biomedical research, and in North America and other countries as a pet, and is most likely a domesticated version of the wild European ferret or polecat (*Mustela putorius* or *M. furo*) [3,6]. Alternatively, it may be related to the steppe polecat (*M. eversmannii*), which it closely resembles in skull morphology [7]. The domesticated ferret, although introduced to North America by the early English settlers some 300 years ago, has not established feral colonies on this continent.

Behavioral differences between the domesticated ferret and the wild European polecat have been documented. The ferret is not as temperamental nor as vigorous and agile as the European polecat [6]. In addition, domesticated ferrets do not develop a fear of humans nor of unfamiliar environments, and are more tractable. The F₁ hybrids of the domesticated ferret and polecat, however, were found to develop a fear of humans when left with their mothers during a critical period between 7.5 and 8.5 weeks of age.
Table 1.1. The Family Mustelidae

<table>
<thead>
<tr>
<th>Genus</th>
<th>Synonym(s)</th>
<th>Range</th>
<th>Member(s)</th>
<th>Number of species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mustela</td>
<td>Grammogale, Lutreola, Putorius</td>
<td></td>
<td>Weasel, stoat, ferret, ermine, mink, polecat</td>
<td>15</td>
</tr>
<tr>
<td>Vormela</td>
<td></td>
<td>Southeast Europe, western China</td>
<td>Marbled polecat</td>
<td>1</td>
</tr>
<tr>
<td>Martes</td>
<td>Charronia</td>
<td>Eurasia, North America</td>
<td>Marten, fisher, sable</td>
<td>7</td>
</tr>
<tr>
<td>Eira</td>
<td>Galera, Tayra</td>
<td>Northeast Mexico to Argentina</td>
<td>Tayra</td>
<td>1</td>
</tr>
<tr>
<td>Galictis</td>
<td>Grison, Grisonella</td>
<td>Southern Mexico to Brazil</td>
<td>Grison</td>
<td>3</td>
</tr>
<tr>
<td>Lyncodon</td>
<td></td>
<td>Argentina, Chile</td>
<td>Patagonian weasel</td>
<td>1</td>
</tr>
<tr>
<td>Ictonyx</td>
<td>Zorilla</td>
<td>Senegal, Ethiopia</td>
<td>Striped polecat</td>
<td>1</td>
</tr>
<tr>
<td>Poecilictis</td>
<td></td>
<td>Sahara region</td>
<td>Striped weasel</td>
<td>1</td>
</tr>
<tr>
<td>Poecilogale</td>
<td></td>
<td>Southern Africa, Zaire, Uganda</td>
<td>White-naped weasel</td>
<td>1</td>
</tr>
<tr>
<td>Gulo</td>
<td></td>
<td>Scandinavia, Siberia, Alaska, Canada, western United States</td>
<td>Wolverine or glutton</td>
<td>1</td>
</tr>
<tr>
<td>Mellivora</td>
<td></td>
<td>Northern India, Arabia, Africa (south of the Sahara)</td>
<td>Ratel or honey badger</td>
<td>1</td>
</tr>
<tr>
<td>Meles</td>
<td></td>
<td>Europe, Japan, southern China</td>
<td>Eurasian badger</td>
<td>1</td>
</tr>
<tr>
<td>Arctonyx</td>
<td></td>
<td>Northern China, northeast India, Sumatra</td>
<td>Hog-badger</td>
<td>1</td>
</tr>
<tr>
<td>Mydaun</td>
<td>Swillotaxus</td>
<td>Sumatra, Java, Borneo, Philippines</td>
<td>Stink-badgers</td>
<td>2</td>
</tr>
<tr>
<td>Tasidea</td>
<td></td>
<td>Southwest Canada to central Mexico</td>
<td>American badger</td>
<td>1</td>
</tr>
<tr>
<td>Melogale</td>
<td>Helictis</td>
<td>Southeast Asia</td>
<td>Ferret-badgers</td>
<td>3</td>
</tr>
<tr>
<td>Mephitis</td>
<td></td>
<td>Canada, United States, Mexico, Nicaragua</td>
<td>Hooded and striped skunks</td>
<td>2</td>
</tr>
<tr>
<td>Spilogale</td>
<td></td>
<td>North and Central America</td>
<td>Spotted skunks</td>
<td>4</td>
</tr>
<tr>
<td>Conepatus</td>
<td></td>
<td>United States to Central and South America</td>
<td>Hog-nosed skunks</td>
<td>7</td>
</tr>
<tr>
<td>Lutra</td>
<td>Lontra, Lutrogale</td>
<td>Eurasia; North, Central, and South America; Africa</td>
<td>Otters</td>
<td>8</td>
</tr>
<tr>
<td>Pteronura</td>
<td></td>
<td>Venezuela to Argentina</td>
<td>Giant otter</td>
<td>1</td>
</tr>
<tr>
<td>Aonyx</td>
<td>Amblonyx, Paraonyx</td>
<td>Africa, southeast Asia</td>
<td>Clawless otters</td>
<td>3</td>
</tr>
<tr>
<td>Enhydra</td>
<td></td>
<td>Siberia, Alaska to California</td>
<td>Sea otter</td>
<td>1</td>
</tr>
</tbody>
</table>

[8]. Imprinting may be involved in this process. When attention response to a rustling noise was tested, the wild ferrets and the F₁ hybrids habituated more rapidly than the domesticated ferret. The F₁ hybrids’ responses depended on their previous environmental history—animals raised outdoors responded differently from those raised indoors. Because the ferret’s natural habitat contrasts greatly with the indoor environment, those ferrets raised indoors showed a greater response. These findings agree with Lorenz’s hypothesis that the behavior of domesticated animals resembles that of juvenile individuals of their wild counterparts [9].
Section I / Biology and Husbandry

The wild ferret is completely interfertile with the European polecat, thus verifying their close genetic relationship. The wild European ferret, however, usually produces only one litter, while the domesticated ferret produces two or more litters yearly [10]. The female ferret and male stoat (*Mustela erminea*) will also produce fertile hybrids [11]. In addition, the F	extsubscript{1} generation of a wild polecat and domesticated ferret is fertile. The steppe polecat can also interbreed with black-footed ferrets [12]. The wild polecat, or ferret native to much of the British Isles and northern Europe, is also known as the fitch, fitchew, foul marten, fitchet, or foumart [5,6].

The Dutch were the first to visit New Zealand in 1642 but received an inhospitable welcome by the native Maoris who killed four of the explorers [13]. The islands weren’t seen again by the Europeans for another 127 years when James Cook made three visits in 1769–1770, 1773–1774, and 1777. Whaling and sealing occupied the first settlers’ primary interests for the next several decades, followed by a period when settlers exploited abundant timber resources. In 1860, gold was discovered and resulted in an influx of tens of thousands, and in 1867, the West Coast reached a peak population of 29,000. Land-hungry colonists expanded acres of farming, and because of a lack of native game to shoot for food, began to import a variety of game animals. Wild rabbits were introduced in 1864 on the South island. By the 1870s, rabbits were creating serious economic loss as well as soil erosion on large tracts of farming land. Flocks of sheep were reduced drastically because of lack of natural grazing pasture. Even though millions of rabbits were killed in an effort to control their devastation on grazing land, there was only the slightest effect on reducing the rabbit population. Natural predators to control the rabbits in New Zealand were lacking, and the farmers therefore turned to importing a predator, the domesticated ferret, already renowned in Europe for its skills as a rabbit hunter. Strong objections were voiced by ornithologists and some of the acclimatization colonists in New Zealand who argued that ferrets, if introduced to control rabbits, would instead decimate the native bird population, especially the flightless birds. The farmers’ demands prevailed, and the first five ferrets were released in the Conway River valley in 1879. They were released by the thousands in 1882–1886 as were two other

Fig. 1.2. The ferret. (Reprinted from Thomson APD (1951) A history of the ferret. J Hist Med 6: 471.)

Fig. 1.3. Ferreting in the Middle Ages, about 1300 AD. (Reprinted from Thomson APD (1951) A history of the ferret. J Hist Med 6: 471.)
mustelids, stoats, and weasels. However, the debate about the merits of the introduction of these predators continued. For example, researchers predicted the consequences of these actions in 1885 in a presentation to the Auckland Institute: “...if stoats, ferrets, weasels... are turned out to destroy rabbits, it will be difficult to protect the birds, as these creatures destroy them, especially ground birds such as kiwis, kakapos, wrens... in Austria we destroy these animals at every opportunity. They are very cunning, and will not take poison while they can get live prey. Rabb...s are much easier destroyed by shooting, netting, or bagging with ferrets when the land becomes more closely settled” [14].

The New Zealand Department of Agriculture bred ferrets for release until 1897, and private breeders continued until 1912, producing approximately 300 a year.

Despite this influx of mustelids, it soon became painfully obvious that the newly introduced predators were not having the desired dramatic effect on rabbit numbers. Instead, within 6 years, there was a drastic decline in native birds in the areas where the mustelids were released. On a positive note, however, the wild rat and mouse population did appear to be reduced. The government finally changed its policy in 1903 and amended the Rabbit Act by removing from the statute protection of the “natural enemies of the rabbit.” Instituting bounties on mustelids had little effect on their numbers and was abandoned in 1950. Even harvesting large numbers of ferrets and stoats for their fur in 1944–1948 made no apparent reduction in their numbers [15].

It wasn’t until the 1950s when rabbits were controlled by chemical means that ferret numbers were significantly reduced [16]. The direct damage to native fauna attributed to the introduction of mustelids are on endangered bird species in New Zealand, particularly flightless birds. Of 18 separate bird populations now considered rare or endangered, 11 of these could have been affected by stoats and/or rats, in addition to other factors such as deforestation or other effects by human encroachment on native habitat. Interestingly, however, there is not a single known extinction or diminution of a bird species in New Zealand that can be solely or definitively attributed to any of the mustelids, despite all that has been written about their destructive predatory behavior. In a detailed survey conducted in 1973, the authors concluded, “It is actually difficult to attribute the decline of any native bird directly to mustelids” [17].

Likewise, throughout the recorded histories of bird species extinctions since 1600, on islands worldwide, only 1% of 163 extinctions were directly attributable to mustelids, compared with 26–54% attributed to cats and rats, respectively [18].

Interestingly, the Department of Natural Resources in Queensland, Australia, have declared pet ferrets illegal under the Rural Protection Act, 1985, stating that buying and selling pets can result in fines up to $60,000. In July 2003, the Rural Lands Protection Act was replaced with the Land protection (Pest and Stock Route Management) Act 2002 and Regulations 2003 and lists ferrets as a prohibited/declared Class 1 pest. A Class 1 Pest under the Act are animals which represent a threat to primary industries, natural resources, and the environment. Under the Act, it is an offense to introduce a ferret into Queensland, feed a ferret, release a ferret, or keep a ferret, unless issued with a permit to do so; permits to own ferrets are issued only to bona fide zoos and wildlife parks [19]. In a National Resources, Mines and Energy (NRME) correspondence, Mr. John English MP, Member for Redlands, wrote to Stephen Robertson MP, Minister for NRME, on behalf of the President of the Queensland Ferret Welfare Society, Barbara Cowell. The following reply was forwarded to Barbara from John English. “Thank you for your letter of 30 April 2004 making representation on behalf of Mrs Barbara Cowell of Macleay Island concerning the keeping of ferrets as pets in Queensland. Only zoos or wildlife parks are able to apply for a permit to keep ferrets in Queensland. There are no provisions in legislation for the keeping of ferrets as pets due to their pest potential. Ferrets are not native to Australia and have the potential to establish wild (feral) populations, as they have already done in New Zealand and the British Isles. In New Zealand, ferrets and stoats have become serious predators of native bird-life and their eggs, particularly ground-nesting birds. Ferrets are also known to be vectors for dangerous exotic diseases such as rabies. Although other states have failed to restrict the keeping of ferrets, they are taking a major risk by allowing these animals to be kept as pets. This concern is highlighted by a recent report of wild ferrets being seen in Tasmania. Also, ferrets established in Western Australia were controlled by trapping. Several states have banned the keeping of wild ferret breeds, known as pole-cats even though there is no reliable way of differentiating between wild and domestic breeds. Queensland, therefore, considers that it is sensible and important to prevent the keeping of this potential pest. I have noted the suggestion for regulation or licensing of keeping. Restricted keeping using permits was investigated for pet domestic rabbits and found to be prohibitively expensive. Section 274(3) of the Land Protection (Pest and Stock Route Management) Act 2002 provides the power for an authorised person to destroy or dispose of a seized pest if a permit for keeping is not produced within 48 hours. An authorised officer
cannot dispose of a seized ferret by handing it to someone to transport to New South Wales because a permit cannot be issued to the person transporting the animal. The authorized officer would need to drive to the border with the animal and it is not appropriate for an officer of my Department to spend time doing this” [19]. The agency still claims that ferrets have pest potential and are a threat to native wildlife, especially small native mammals and ground dwelling and nesting birds.

In addition, the state of Washington had listed the ferret (*Mustela putorius*) as a feral animal on San Juan Island, where it was initially introduced together with other predators to control an excessive population of European rabbits. Because of the competition, the population of native mink (*M. vison*) on the island has been reduced in number [20,21]. However, in a letter dated April 14, 1988 from the Nongame Program Manager of the Department of Wildlife in Washington State, Mr. Juelsen states to Bill Philips of the California Domestic Ferret Association regarding the alleged ferret colony on San Juan Island, “I am prepared to state that, to the best of my knowledge, there are no ferrets living in Washington that prey upon native wildlife. Those rabbit populations dramatically decreased a few years ago and I have been unable to find anyone who has observed a ferret there since.” In addition Mr. Phillips surveyed all 50 states and received a reply, in writing, to the effect that no feral colonies of the domestic ferret were known to exist anywhere in the United States. Some officials suggested that sightings of ferrets could either be the result of escaped pets and strays or mistaken identity with the long-tailed weasel (*M. frenata*).

**MORPHOLOGY**

The ferret has a long body, with short muscular legs and a long tail. The adult ferret’s average body length is 44–46 cm from the nose to the tip of the tail. Some of its anatomic features resemble those of the cat and dog—the anterior and lateral portions of its skull resembles that of a cat, not a dog. On the other hand, the zygomatic bones of the eye orbits of the ferret and dog are open, while those of a cat are almost closed [22].

As a result of its behavioral traits and burrowing instincts, the ferret has developed certain anatomic adaptations. It is postulated that, because of its burrowing nature, the ferret’s long neck and placement of the carotid arteries may help the ferret maintain sufficient cerebral blood flow when it turns its head in tight confined spaces (see Chapter 2) [23]. The compliant chest wall, total lung capacity, and respiratory reserve, which is very large in comparison to body size, are anatomic adaptations. The relatively large-diameter airway and long trachea result in a lower central airway and pulmonary resistances in comparison to those of other animals of similar size (see Chapter 4) [24]. It is important to note that the airways of the ferret grow in length and diameter in proportion to body length [25]. Similar findings have been recorded in humans [26].

The ferret’s short digestive tract is characteristic of other carnivores, but a cecum and appendix are absent in this species. Also, the large intestine is unique, because there is no external anatomic division between the ileum and the colon, and thus the lower intestine appears grossly as one long, undifferentiated organ [27]. Anatomy is discussed in greater detail elsewhere (see Chapter 2).

**Coat Colors**

The genetics of coat colors has been described and is based largely on studies conducted by Fara Shimbo [28,29]. These genetic coat color traits have been highlighted in the text by John Lewington [30]. However, it is important to note that unless the important characteristics, such as pigmentation of both guard coat and under coat, as well as skin pigment and markings, are carefully documented, it may never be possible to fully characterize the genetics of coat colors of ferrets [31]. Having large numbers of ferrets for extensive breeding trials over many generations will be required to achieve these goals.

Readily available commercial stocks, based on coat color, are albino (English; Fig. 1.4), sable or fitch (black guard hair; Fig. 1.5), Siamese (brown guard hair; Fig. 1.6), silver mitt (sable with white chest and feet; Fig. 1.7), and Siamese-silver mitt (Siamese with white chest and feet) [32]. The fitch or so-called wild coat color is the most common coat color, recognized by yellow-buff fur with patches of black or dark brown, particularly on the tail and limbs [33]. The facial fur is somewhat lighter, with a dark mask over the eyes that is less marked in neutered or immature animals. The eyes are usually dark brown.

The albino (with a nonpigmented iris) is also seen frequently, but this coat color is recessive to the pigmented wild phenotype. The pet industry is currently promoting additional coat colors. Varieties of Siamese are chocolate (dark brown), cinnamon (reddish brown), and butterscotch (very light tan) [34]. Other mutations have produced a wide selection of coat colors and patterns. Black-eyed whites are born white and remain pure white and have dark eyes. Ferrets of any body color with white paws are known as mitts. Predominantly dark-colored young ferrets with white feet and some white in their coats are called silver mitts. A young silver ferret usually has some white hair in the mask, making it indistinct, and often has ventral
patches of white, commonly including a spot on each stifle. With every molt, more white appears throughout the coat, until the ferret is almost pure white. Different markings have become common in ferrets. Some have white toes on one or more feet, or spots or rings of white on their tails. Ferrets that have white heads and bibs are known as pandas. A blaze, or a single streak of white in the center of the head above the mask, is another pattern found. Panda or blaze markings appear to be dominant phenotypes and can be superimposed on any coat color. More recent mutations have resulted in pastel- or champagne-colored ferrets, which are solid pale beige with no masks, and angoras, which have much longer, fuzzier coats than usual. Ferrets carrying the genes that usually produce silver mitts also produce occasional black-eyed whites or odd-colored kits [30]. Mating silver mitts or black-eyed whites with each other can result in severe congenital abnormalities in the offspring, fetal resorption, or abortion. Congenital abnormalities are not commonly associated with other common coat colors.
The species had last been sighted in South Dakota in the early 1970s, and by 1980, many believed that the black-footed ferret was extinct [39]. In 1981, however, a rancher’s dog killed a weasel-like creature near Meeteese, Wyoming. Luckily, the animal was retrieved by the rancher’s wife, and a local taxidermist recognized it as a black-footed ferret [39]. Biologists from the Department of Fish and Wildlife Service and from the Biota Research and Consulting Company soon converged on the area and documented new sightings of the black-footed ferret.

Because they are nocturnal and spend most of their time in underground burrows, they are difficult to track. The 80,000-acre area of prairie dog colonies was surveyed, and it was estimated that there was a population of 60 ferrets for the summer of 1982, 88 in 1983, and 128 in 1984 [37]. Recent studies indicate that ferrets hunt over a 100-acre area, which is a large range for a small mammal. Therefore, only large prairie dog complexes (several thousand acres), made of many closely spaced prairie dog colonies, can support a successful breeding population of 100–200 black-footed ferrets [40]. Importantly, field tests are ongoing to evaluate a new vaccine developed by the National Wildlife Health Center to protect prairie dogs against sylvatic plague [41]. In the summer of 1985, the increasing black-footed population underwent a dramatic reversal. The first count, in August of 1985, estimated a dramatic decrease—only 58 ferrets. This number declined to 31 in October of the same year. Canine distemper, often reported in wild carnivores, had been introduced into the colony and, of the 12 ferrets brought into captivity, 6 died of the disease.

**North American Black-Footed Ferret**

The black-footed ferret, *M. nigripes*, the North American representative of the Holarctic group of polecat species, probably made its first appearance in North America about 100,000 years ago (Fig. 1.8). It is closely related to *M. eversmannii*, the steppe polecat, which unlike the black-footed ferret, utilizes several sources of food. Although suggested to be conspecific, morphological comparisons [35] and more recent molecular studies [36] indicate that *M. nigripes* and *M. eversmannii* are indeed separate species. It was at one time prevalent on the North American plains where its main prey, the prairie dog, lived in large colonies called “prairie dog towns” [37]. Consequently, in the first half of the twentieth century, large-scale prairie dog eradication programs resulted in placement of the black-footed ferret on the endangered species list in 1967.

In the 1960s and 1970s, researchers attempted to breed the animal in captivity and to understand its biology and diseases. These attempts were basically unsuccessful, and the programs were abandoned [38].