Introduction

The first reports of the use of squirrel monkeys in research were published about 65 yr ago (Kliiver 1933). The early work of Kliiver at the University of Chicago provided the first description of housing methods and experimental use of squirrel monkeys. In 1947, the first births in captivity were reported (Kliiver and Brunschwig 1947); and 2 yr later, the National Heart Institute awarded the first grant to establish a breeding colony of squirrel monkeys to the Anatomy Department of the Louisiana State University School of Medicine (Goss et al. 1968). During the next 10 yr, Goss and coworkers learned that squirrel monkeys adapted well to laboratory conditions and were easy to handle; however, their reproduction was poor. Of 41 term pregnancies, 22 resulted in living births (with five subsequent deaths) and 17 were stillbirths or abortions. The National Heart Institute’s support for this breeding colony was subsequently ended.

By 1975, the Animal Resources Branch (now the Comparative Medicine Area) of the Division of Research Resources (now the National Center for Research Resources) of the National Institutes of Health (NIH) had recognized the importance of the squirrel monkey in a number of biomedical research areas. A production breeding contract was awarded in 1975 to the Caribbean Primate Research Center (CPRC) to meet the need for squirrel monkeys in NIH-sponsored research. By 1979, production at the CPRC remained far below expectations, prompting a review of reproduction methods in this genus. Other facilities breeding squirrel monkeys also reported less successful reproduction than that of other commonly used nonhuman primates (Johnsen and Whitehair 1986). It was determined that the body of knowledge of the basic biology (more specifically reproductive biology) of squirrel monkeys was not adequate to resolve the difficulties in captive breeding. This judgment prompted a decision to convert the breeding contract at the CPRC to a grant that combined production breeding with a research program focused on better understanding the biology of Saimiri. It was decided that a combined research and resource program focusing on reproductive biology, husbandry, and veterinary care was needed to improve reproduction and ensure a continuing supply of squirrel monkeys for NIH-supported research. The NIH awarded this grant in 1980 to the University of South Alabama to establish a national Squirrel Monkey Breeding and Research Resource (SMBRR).

The SMBRR’s initial grant period (1980-1985) was devoted to the development of a Bolivian squirrel monkey breeding resource (Saimiri boliviensis boliviensis). The objectives of the resource were to establish a self-sustaining breeding colony to help meet the needs of NIH grantees using squirrel monkeys and to carry out a multidisciplinary research program to better understand the biology and behavior of squirrel monkeys. The SMBRR has expanded since 1980 to include Peruvian (Saimiri boliviensis peruviensis) and Guyanese (Saimiri sciureus sciureus) squirrel monkey breeding colonies.

Advantages of Squirrel Monkeys As Research Subjects

Squirrel monkeys (Saimiri spp.) are the most commonly used neotropical primates in biomedical research in the United States. Their physical characteristics, including small size and ease of handling, contribute to their desirability as research subjects. The mean body weight of adult squirrel monkeys is less than 1 kg compared with female rhesus monkeys, which usually weigh 4 to 5 kg. As a result, much smaller doses of synthesized compounds are necessary when using squirrel monkeys to test new drugs, an important advantage when studies require administration of expensive compounds. Squirrel monkeys easily adapt to laboratory housing and can be maintained in smaller spaces and less expensive cages than larger primates such as macaques and baboons. This characteristic is especially important in facilities with space limitations.

The growing concern with viral disease transmission from exposures to macaques shedding cercopithecine herpesvirus 1 (B virus) since the tragic deaths of laboratory workers in Florida (CDC 1987), Michigan (CDC 1989), Texas, and Georgia (CDC 1998) is likely to increase the interest of investigators and institutions in using squirrel monkeys.
Because there is less risk of zoonotic disease transmission with squirrel monkey and other neotropical primates than with macaques and other Old World primates, and accidental exposures from bites and scratches can be managed in a manner similar to those from dogs and cats, personal protective equipment required for handling squirrel monkeys is less extensive. The reduced risk to laboratory workers combined with the ease of handling this small primate allows more procedures to be carried out without chemical restraint or expensive handling equipment. In addition, squirrel monkeys are easily habituated to handling, which further reduces stress from manipulation. For these reasons, experimental procedures that must be done without sedation can be carried out relatively easily in squirrel monkeys.

**Taxonomy: Genotypic and Phenotypic Characteristics**

All squirrel monkeys were once considered to be a single species *(S. sciureus)* with several geographically separated subspecies. However, karyotypic and phenotypic information gathered in the early 1980s led to the conclusion by Hershkovitz (1984) that squirrel monkeys should be classified as a single genus with four species and nine subspecies. Studies conducted by Assis and Barros (1987), Da Silva et al. (1987), and VandeBerg et al. (1990) support the taxonomic classification of Hershkovitz.

The most commonly used phenotypic characteristic for identification is the shape of the patch of nonpigmented hair above the eyes. Squirrel monkeys are divided into two groups based on this phenotypic characteristic. Those belonging to the *S. sciureus* group are classified as “gothic arch” squirrel monkeys possessing a pointed arch of whitish hair above each eye. Those belonging to the *S. boliviensis* group are referred to as “roman arch” squirrel monkeys and are characterized by more shallow semicircular patterns above the eyes. The use of this phenotypic characteristic for identifying species/subspecies of squirrel monkeys was first reported by MacLean (1964) and later by Cooper (1968), and its usefulness was later confirmed by Hershkovitz (1984). Additional phenotypic characteristics include differences in coloration of the hair on the head and body, which can range from subtle to obvious. Squirrel monkeys of the roman arch variety usually have black hair crowning their heads, although exceptions exist (Hershkovitz 1984); and gothic arch squirrel monkeys usually have a gray green agouti coloration. *S. sciureus sciureus*, the Guyanese squirrel monkey, also possesses a pattern of pigmented hairs within the patch of whitish hair above each eye, which resembles an eyebrow (Ariga et al. 1978).

Precise identification of squirrel monkeys often requires both phenotypic and karyotypic examination. All squirrel monkey species and subspecies that have been examined thus far have 44 (diploid) chromosomes; however, they vary in their number of acrocentric autosomes from five to seven. More certain identification can be made by counting the number of acrocentric autosomes and observing the periocular patches (Ariga et al. 1978). Sexual dimorphism is also observed in squirrel monkeys although sex differences are less distinct than in many Old World primates. Male squirrel monkeys are 25 to 30% heavier than females, and canine teeth are larger and longer in males. In Table 1, the species and subspecies of squirrel monkeys are listed with the nomenclature suggested by Hershkovitz (1984).

A substantial body of information has accumulated over the past 30 yr, providing convincing evidence that species and subspecies of squirrel monkeys vary in their susceptibil-

### Table 1 Selected taxonomic characteristics of the squirrel monkey*

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Chromosome no. (diploid)</th>
<th>Variety*</th>
<th>Acrocentric autosomes</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Saimiri sciureus sciureus</em></td>
<td>44</td>
<td>Gothic</td>
<td>7</td>
</tr>
<tr>
<td><em>S. sciureus macrodon</em></td>
<td>44</td>
<td>Gothic</td>
<td>6</td>
</tr>
<tr>
<td><em>S. sciureus cassiquiarensis</em></td>
<td>?</td>
<td>Gothic</td>
<td>?</td>
</tr>
<tr>
<td><em>S. sciureus albigena</em></td>
<td>?</td>
<td>Gothic</td>
<td>?</td>
</tr>
<tr>
<td><em>Saimiri boliviensis boliviensis</em></td>
<td>44</td>
<td>Roman</td>
<td>6</td>
</tr>
<tr>
<td><em>S. boliviensis peruviensis</em></td>
<td>44</td>
<td>Roman</td>
<td>5</td>
</tr>
<tr>
<td><em>Saimiri oerstedii oerstedii</em></td>
<td>44</td>
<td>Gothic</td>
<td>5</td>
</tr>
<tr>
<td><em>S. oerstedii citrinellis</em></td>
<td>?</td>
<td>Gothic</td>
<td>?</td>
</tr>
<tr>
<td><em>Saimiri ustus</em></td>
<td>44</td>
<td>Gothic</td>
<td>5</td>
</tr>
</tbody>
</table>


Based on arching pattern created by distribution of pigmented and white hair in the periocular patch (gothic: elongated, peaked arch; roman: semicircular arch).
Division of Quarantine, National Center for Infectious Diseases

Thus, by the late 1980s, only Peruvian squirrel monkeys (S. sciureus sciureus) were imported from Suriname between 1971 and 1982. Peruvian squirrel monkeys have been exported from Peru to the United States in large numbers in the 1960s (Cooper 1968). However, the governments of South America began banning export of primates indigenous to their countries in the 1970s. The exportation of the Bolivian squirrel monkey (S. boliviensis boliviensis), a species considered especially desirable for malaria vaccine studies, was banned by the Bolivian government in 1983. Thus, by the late 1980s, only Peruvian squirrel monkeys (S. boliviensis peruviensis) were available from the wild.

Sources of Squirrel Monkeys for Research

Once plentiful and available at modest cost from importers, squirrel monkeys were imported to the United States in large numbers in the 1960s (Cooper 1968). However, the governments of South America began banning export of primates indigenous to their countries in the 1970s. The exportation of the Bolivian squirrel monkey (S. boliviensis boliviensis), a species considered especially desirable for malaria vaccine studies, was banned by the Bolivian government in 1983. Thus, by the late 1980s, only Peruvian squirrel monkeys (S. boliviensis peruviensis) were available from the wild.

Feral Squirrel Monkeys

The Peruvian Primatology Project is administered jointly through the Pan-American Health Organization and the Peruvian government. In the past 2 yr, fewer than 100 feral Peruvian squirrel monkeys have been exported from Peru to the United States, and 719 Guayanese squirrel monkeys (S. sciureus sciureus) were imported from Suriname between September 1997 and December 1998 (T. A. DeMarcus, Division of Quarantine, National Center for Infectious Diseases, Centers for Disease Control and Prevention, personal communication, 1999). It is not possible to predict whether squirrel monkeys from these sources will remain available.

Saimiri oerstedii citrinellus is an endangered squirrel monkey species of which fewer than 1000 are believed to exist in the wild (Boinski 1985). These animals are not available for export; however, noninvasive field research and other efforts to improve their chances for survival are possible. The focal point for these efforts is Costa Rica’s wildlife rescue center, Jardin Gaia, located near Manuel Antonio National Park on Costa Rica’s Pacific coast.

All feral-origin squirrel monkeys share similar weaknesses as research subjects. They are of unknown age, medical history, genetic background, and reproductive history. Furthermore, feral animals frequently have parasitic infections, which reduces their desirability for some types of research (Abee 1985). For example, squirrel monkeys naturally infected with malaria are not suitable for malaria vaccine development studies.

Domestic Squirrel Monkey Breeding Resources

Until 1994, there were three federally supported squirrel monkey breeding resources in the United States. One of these colonies was maintained at the University of South Alabama and consisted of approximately 270 squirrel monkeys supported by the United States Agency for International Development. This colony was used for testing the efficacy of potential vaccines against malaria. This breeding contract expired in 1994, and the animals were donated to the Centers for Disease Control and Prevention (CDC) for its malaria vaccine development program. The CDC subsequently transferred most of these squirrel monkeys to the SMBRR at the University of South Alabama, and their progeny are available to the CDC for malaria vaccine testing. The second colony, consisting of approximately 150 Peruvian squirrel monkeys, belonged to the National Aeronautics and Space Administration and was used as a resource for aerospace research. This breeding contract at the University of Wisconsin was terminated and the colony given to the Mannheimer Foundation, a private entity, in south Florida.

The SMBRR is the only remaining federally supported squirrel monkey breeding resource in the United States. Census figures for the three types of squirrel monkeys maintained in breeding groups at the SMBRR are listed in Table 2. The SMBRR provides squirrel monkeys, their tissues, and their biological fluids to NIH grantees throughout the United States.

South American Squirrel Monkey Breeding Resources

Two squirrel monkey breeding colonies are located in South America. The larger, located in French Guiana at the Pasteur Institute (de Thoisy and Contamin 1998), is maintained at two sites where approximately 1000 squirrel monkeys (S. sciureus sciureus) are either housed in an indoor laboratory or are semi-free ranging on an island located off the coast of Guiana. The other breeding colony is maintained at the Centro Argentino De Primates (CAPRIM1) in Corrientes, Argentina (Colillas et al. 1980). The squirrel monkey breeding colony at CAPRIM is of particular research value because...
Table 2  Squirrel Monkey Breeding and Research Resource census, University of South Alabama, Mobile, Alabama, February 25, 1999

<table>
<thead>
<tr>
<th>Species</th>
<th>Sex</th>
<th>Infants</th>
<th>Yearlings</th>
<th>Juveniles</th>
<th>Adults</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saimiri boliviensis boliviensis</td>
<td>F</td>
<td>38</td>
<td>33</td>
<td>156</td>
<td>227</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>37</td>
<td>14</td>
<td>24</td>
<td>75</td>
<td></td>
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<tr>
<td>Total</td>
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<td>38</td>
<td>47</td>
<td>180</td>
<td>302</td>
<td></td>
</tr>
<tr>
<td>Saimiri sciureus</td>
<td>F</td>
<td>17</td>
<td></td>
<td>26</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>15</td>
<td></td>
<td>6</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>32</td>
<td></td>
<td>32</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>Saimiri boliviensis peruviensis</td>
<td>F</td>
<td>1</td>
<td>9</td>
<td>3</td>
<td>23</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>11</td>
<td>1</td>
<td>6</td>
<td>18</td>
<td>54</td>
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<tr>
<td>Total</td>
<td></td>
<td>12</td>
<td>10</td>
<td>39</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>1</td>
<td>127</td>
<td>51</td>
<td>241</td>
<td>420</td>
</tr>
</tbody>
</table>

it is composed of Bolivian squirrel monkeys no longer available from any other sources. The SMBRR and CAPRIM established an agreement in 1998 to share resources, thus providing an additional source of Bolivian squirrel monkeys to NIH grantees.

Useful Squirrel Monkey Research Areas

The squirrel monkey has proven to be valuable in a number of areas of biomedical research, and it remains the most commonly studied neotropical primate in the United States. Its value as a research subject is exemplified by the publication of two textbooks devoted entirely to the squirrel monkey (Rosenblum and Coe 1985; Rosenblum and Cooper 1968) and reviews within this issue of the Journal (Brady 2000; Galland 2000; Scammell 2000; Williams and Glasgow 2000) that further describe important contributions of the squirrel monkey.

Although the virtues of the squirrel monkey as a research subject were described as early as 1933 (Kliiber 1933), it was not until the late 1950s that reports began to emerge that ignited the interests of biomedical scientists who were searching for nonhuman primate surrogates for the study of human physiology and disease.

Their small size, ease of handling, and ability to tolerate high gravitational forces made the squirrel monkey an ideal subject for physiological studies of the effects of space flight. In December 1958 and again in May 1959, squirrel monkeys were launched in suborbital flights using the Jupiter rocket. These early studies of the physiological effects of acceleration, reentry, and deceleration provided important evidence that human beings could withstand the rigors of space flight. The use of the squirrel monkey in the space program of the United States has been reviewed (Beischer 1968).

In 1964, Middleton et al. reported that squirrel monkeys maintained under laboratory conditions had fatty streaks and plaques in their aortas resembling human atherosclerosis. This finding, followed by the discovery that squirrel monkeys captured in the wild had naturally occurring atherosclerotic lesions (Middleton et al. 1967), led investigators to carry out studies in which squirrel monkeys were fed atherogenic diets to induce more severe or complicated atherosclerotic lesions (Lofland et al. 1967; Malinow et al. 1966). For the next decade, a number of articles were published describing the pathogenesis of experimentally induced atherosclerosis and the regulation of plasma lipids and cholesterol in squirrel monkeys. The use of squirrel monkeys in cardiovascular research has been reviewed by Strickland and Clarkson (1985).

The use of experimental diets containing high fat and cholesterol to induce atherosclerosis serendipitously revealed another metabolic disorder resembling a human disease. Many squirrel monkeys fed these diets developed cholelithiasis. Thus, by the early 1970s, reports began to appear in the scientific literature describing the experimental induction of cholelithiasis in squirrel monkeys (Lofland et al. 1974; Osuga and Portman 1971).

While studies of experimentally induced cardiovascular disease and cholelithiasis were being carried out, another laboratory reported induction of ovulation using parenteral hormone administration and artificial insemination in squirrel monkeys (Bennett 1967a,b). These reports were among the first to describe successful induction of ovulation and artificial insemination in a nonhuman primate. By the early 1980s, a number of laboratories had published reports describing various aspects of the reproductive physiology of the squirrel monkey. This work has been reviewed by Dukelow (1983, 1985).

The large number of studies using the squirrel monkey
over the past 40 yr has provided a wealth of basic information about the biology of this neotropical primate. This information continues to provide important baseline data for studies being carried out today and for future studies. Although research methods and approaches have changed radically over the past decade with advances in molecular and cellular biology, the use of squirrel monkeys has remained relatively constant. The squirrel monkey was cited in 3583 articles published from January 1990 to February 1999 (PIC 1999).2 In Table 3, articles citing squirrel monkeys by scientific area from 1995 through 1998 are listed. During those years, studies of the central nervous system, behavior/learning, and perception have yielded the most publications in the scientific literature.

### Table 3 Articles in which squirrel monkeys are cited

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteriology/Virology and Immunology</td>
<td>16</td>
<td>24</td>
<td>29</td>
<td>13</td>
</tr>
<tr>
<td>Behavior/Learning and Perception</td>
<td>41</td>
<td>39</td>
<td>62</td>
<td>46</td>
</tr>
<tr>
<td>Biochemistry/Metabolism and Nutrition</td>
<td>5</td>
<td>12</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Biological Clocks</td>
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<td>0</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Cardiovascular/Blood and Body Fluids</td>
<td>5</td>
<td>6</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Dental and Oral Structures/Ear and Acoustic Nerve</td>
<td>4</td>
<td>7</td>
<td>4</td>
<td>5</td>
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<tr>
<td>Developmental Biology</td>
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<td>1</td>
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<tr>
<td>Ecology and Conservation</td>
<td>10</td>
<td>19</td>
<td>19</td>
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<td>Environmental Health and Space Biology</td>
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<td>3</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Eye and Optic Nerve</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Genetics</td>
<td>17</td>
<td>17</td>
<td>14</td>
<td>31</td>
</tr>
<tr>
<td>Gerontology</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Molecular and Cellular Biology</td>
<td>9</td>
<td>5</td>
<td>8</td>
<td>7</td>
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<tr>
<td>Musculoskeletal System</td>
<td>20</td>
<td>9</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Neoplasia</td>
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<td>5</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Nervous System</td>
<td>66</td>
<td>107</td>
<td>93</td>
<td>95</td>
</tr>
<tr>
<td>Parasitology</td>
<td>8</td>
<td>19</td>
<td>18</td>
<td>22</td>
</tr>
<tr>
<td>Pharmacology/Toxicology and Therapeutics</td>
<td>45</td>
<td>45</td>
<td>44</td>
<td>26</td>
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<tr>
<td>Primatology (General) and Paleoprimatology</td>
<td>28</td>
<td>32</td>
<td>35</td>
<td>34</td>
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<td>Reproductive/Endocrine Systems</td>
<td>14</td>
<td>25</td>
<td>19</td>
<td>6</td>
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<tr>
<td>Other Research Areas</td>
<td>33</td>
<td>37</td>
<td>29</td>
<td>34</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>330</strong></td>
<td><strong>423</strong></td>
<td><strong>414</strong></td>
<td><strong>370</strong></td>
</tr>
</tbody>
</table>


Research Using Squirrel Monkeys at the SMBRR

In addition to maintaining a breeding colony to meet the needs of NIH grantees who use squirrel monkeys in their research, the SMBRR maintains active collaborative and independent research programs that use squirrel monkeys to address human health issues. The SMBRR provides the opportunity for visiting scientists to carry out studies with squirrel monkeys in addition to sponsoring ongoing studies carried out by resident investigators. Facilities that include both office and laboratory space are provided in the Primate Research Laboratory at the University of South Alabama for visiting scientists working at the SMBRR. Specific areas of research conducted at the SMBRR are briefly described below and have included malaria vaccine development, Creutzfeldt-Jakob disease, biomechanics of labor and delivery, pelvic organ prolapse (POP1), and emphysema.

#### Malaria Vaccine Development

The squirrel monkey is an important animal model for malaria vaccine development studies. Because *Plasmodium* spp., which cause malaria, are host specific, animals used for studies of human malaria must be susceptible to the same strains of *Plasmodium* that cause disease in humans. The Bolivian squirrel monkey has been shown to be a superior model for studies of the pathogenesis of *Plasmodium falciparum* Indochina I (Whiteley et al. 1987). Experimentally infected Bolivian squirrel monkeys developed lesions and signs similar to those reported in the human disease.
Guyanese squirrel monkeys (*S. sciureus sciureus*) experimentally infected at the same time were found to be a less suitable model. These differences in susceptibility to experimental malaria infections emphasize the importance of species identification when using squirrel monkeys. The SMBRR maintains a breeding resource to meet the needs of the malaria vaccine development program at the CDC.

**Creutzfeldt-Jakob Disease**

Considerable international concern has been raised regarding a potential epidemic of a new variant of Creutzfeldt-Jakob disease (CJD), a fatal spongiform encephalopathy of humans. This new variant was first discovered in Britain and later in several other European countries (Bruce et al. 1997; Will et al. 1996). Concern that new variant CJD is transmitted to humans by consumption of contaminated beef has prompted international research efforts to determine its pathogenesis and epidemiology. Concern has been heightened by the possibility that human blood supplies and human blood products may be at risk from donors who are incubating this disease (Culota 1995; Ricketts et al. 1997). For many years, the squirrel monkey has been recognized as one of the nonhuman primate species most susceptible to experimental infection with CJD and other transmissible spongiform encephalopathies (Brown et al. 1994; Fuchs et al. 1997; Schätzl et al. 1997; Zlotnik et al. 1974). The susceptibility of squirrel monkeys to experimental CJD infection is believed to be genetic; the squirrel monkey genome is 93.8% homologous to the human PrP sequence that is associated with increased susceptibility to infection in humans (Schätzl et al. 1997).

**Biomechanics of Labor and Delivery**

In women, the flexed position of the fetus and its rotating course through the birth canal are well documented. In other primates, the mechanism of labor is unknown. Despite this lack of comparative data, it was assumed that the human obstetric mechanism was unique, and anthropologists have disputed when and why the transition to the human mechanism occurred.

The squirrel monkey was selected for study to better understand the biomechanics of labor and delivery in nonhuman primates. A study using seven pregnant squirrel monkeys was carried out at the SMBRR to document the initiating events and underlying pathophysiology of POP (early fall). These studies have confirmed that multiparous squirrel monkeys develop lesions resembling POP in women.

**Pelvic Organ Prolapse**

The similarities in labor and delivery of women and squirrel monkeys (Stoller 1995), and a report of lesions consistent with POP in a small group of aged squirrel monkeys from the Scott &White Clinic and Hospital in Temple, Texas (Coates et al. 1995a), suggest that the squirrel monkey may develop lesions of POP that closely resemble the disease of women. POP afflicts older women, and the incidence of this disease appears to be increasing as the number of older women increases. Both parity and levels of circulating steroid hormones are thought to influence its development; however, the initiating events and underlying pathophysiology of POP are poorly understood. The delay between insult (presumably parturition) and onset of clinical signs has further complicated research efforts.

Studies were begun at the SMBRR in 1994 to assess the incidence and characteristics of POP in a large group of squirrel monkeys with documented reproductive histories (Coates et al. 1995b). Female squirrel monkeys 3 yr of age and older were evaluated for the presence of POP. The external genitalia were photographed, measured, and evaluated using a modified grading system developed for women (Shull et al. 1992). This investigation revealed that the incidence of POP in squirrel monkeys increased with age and parity. Additional evaluation in 1995 revealed that the incidence and severity of POP changed depending on whether the evaluation was made in the breeding season (spring) or nonbreeding season (early fall). These studies have confirmed that multiparous squirrel monkeys develop lesions resembling POP in women.

**Emphysema**

Recent studies with rats have shown that retinoic acid treatment during the postnatal period increased the number of pulmonary alveoli (Massaro and Massaro 1996). A subsequent study using adult rats with elastase-induced emphysema showed abrogation of emphysema with new alveoli production after retinoic acid treatment (Massaro and Massaro 1997). Although experimental emphysema had been induced using elastase and/or papain in hamsters (Hayes et al. 1975; Kaplan et al. 1973), rats (Gross et al. 1964), rabbits (Caldwell 1971), and dogs (Pushpakom et al. 1970), it had not been reported in nonhuman primates. Visiting scientists from the Lung Biology Laboratory of the Georgetown University School of Medicine began a study at the SMBRR in 1996 to determine whether experimental emphysema could be produced in the squirrel monkey. The squirrel monkey was selected for these preliminary studies because its small size would allow relatively smaller amounts of elastase to be used than that required for larger primates. Based in part on pre-
liminary studies carried out at the SMBRR, a research grant from the National Heart, Lung, and Blood Institute of NIH was awarded to carry out studies to determine whether retinoic acid treatment will abrogate emphysema in a non-human primate. It is anticipated that this study will provide new information on the cellular and molecular action of retinoic acid on regeneration of alveoli in a primate model.

Concluding Remarks

The squirrel monkey has a number of qualities that make it an important biomedical research model. Its small size and ease of handling are particularly desirable for studies requiring frequent handling without sedation. The susceptibility of squirrel monkeys to diseases such as CJD and human malaria for which few other animal models exist further add to the value of this primate.

To ensure a reliable supply of squirrel monkeys and reduce the need to import wild animals, captive breeding colonies (breeding resources) are the only option. Breeding resources provide the opportunity to produce well-defined animals with respect to medical and reproductive history, known genetic and phenotypic characteristics, and pedigree. The use of well-defined squirrel monkeys can reduce the number needed and improve the research. Breeding resources also provide unique opportunities to carry out research aimed at advancing our understanding of the biology of squirrel monkeys while emphasizing research aimed at discovering biological characteristics that can be utilized to model disease states of human beings. Much of this research can only be carried out in colonies where relatively large numbers of animals are available for study. By conducting research within the breeding resource in addition to breeding, these scarce primates can be used efficiently to address human health problems while veterinary medical care and husbandry practices are also improved. Due to the uncertain availability of imported squirrel monkeys and the difficulties associated with their importation, future research using this neotropical primate may depend entirely on domestic breeding resources.

References


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